The American

GAS LIGHT JOURNAL.

(ILLUSTRATED.)

DEVOTED TO THE INTERESTS OF

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—AND—

GENERAL SCIENCE.

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BRIEFLY TOLD.

THE OUTLOOK FOR GAS PRICES IN BROOKLYN, NEW YORK AND JERSEY CITY.—We will have to admit, at the outset, that the names of these three cities have rarely been coupled in any single business matter, but as oddities are noteworthy, and as those who have to do with oddities are seldom surprised, no matter what the circumstances may be, it looks to have come to our portion to say that greater New York and lesser New Jersey are confronted with a trouble which afflicts them both—that is, the gas men of the three cities have been afflicted with hard boils on their anatomies, the growth and fruitification of which are almost at the sloughing point. The gas men are solely responsible for the appearance of the ulcers, for, very much after the nature of rugged youth—whose blind indifference to that which is to follow their callow period is a well established, in fact, an everyday fact—they made hay while the sun shone, neglectful of the wisdom that a time of disorder was likely to come. Those who have witnessed the rottenness of the financiering methods of the owners of the New York, Brooklyn and Jersey City Gas Companies during the past decade are not surprised at the present condition of things. In New York, verbal agreements entered into have been treated like the frothy pledges made by boon companions in their most cuppy, hilarious stages; in Brooklyn, that center of restful peace, where the aim of the most respectable seems to be to hold that the last with whom they have had business dealings was the worst scoundrel that a conference was ever had with, simple blackmail seems to have been the game; and in Jersey City, grab-all and keep-all ruled the roost. Our readers outside of the three cities will likely say the foregoing is incoherent; to them it may be, but those who have to do with the internal policy of the three named cities, in so far as the gas supply of the same is concerned, will have no trouble in recognizing the entire rationalness of what we have said. However, frothy pledges, broken and unbroken, blackmail and hoggishness are but poor chains wherewith to moor a boat in even safe waters, and the strain has reached the stretch where the links have parted. In New York, everyone conversant with the gas business for the past five years knows that the ruling gas rate has been too high, that the Companies have kept the price at a figure which invited the attention of restless "promoters," from the West and elsewhere, who cared not who was burned as long as they saved their own wings. The most shining example of this is shown in the case of the concern known now as the New York and East River Gas Company, which followed that other no less haloed organization that sprang from the loins of the Schulz-Thurber-Sherwood-Bixby-Andrews combination and its assigns, and which now reposes under the double halo that is supposed to encircle the head of St. Russell Sage. The Western gentleman who "floated" the New York and East River goosequill—for its tunnel under the East River could be designated by no more appropriate name—and the ostensible manager of the Standard Company, then, ought to make common cause, for they have succeeded in disturbing the regularly organized gas supply of this city in no small measure; but they are still wide of their ultimate mark, very much as Samson was when he pulled down the temple and died in its ruins. Where is Standard preferred stock coming in, to say nothing of its common rags, when the row which the East River and itself has originated is concluded? Do these people think that the Consolidated, the Mutual and the Equitable

Companies are not able to keep them where they are? The one on the banks of the Harlem, north and south, the other on the marshes of Ravenswood, with its poorly constructed sewer betwixt New York and Long Island. Those who differ with us will say that time alone will tell; but we would put ourselves on record as asserting that when the battle has ended the real gas companies of the city will be where they now are—on top. The Brooklyn situation is dirtier still than is the New York one, for over there no outsiders have interfered for over 10 years, or after the time when the Fulton-Municipal, and some of those interested in the Williamsburgh Company, managed to frighten the others—save the Nassau—into paying "rent" for the privilege of making gas in their respective districts. We are assured that history repeats itself, and it does beyond a doubt; but not always in the same way, and in our belief the tactics which were so successfully pursued in 1880–83 will fail in 1894. The times are changed, and those who were frightened in 1883 are 10 years older than they were then—or, for instance, they are about the same age now that those who then frightened them were 10 years ago. An old dog is slow to learn new tricks, and the younger dog, if he is well bred, can ever be counted on to improve on the tricks of his sires; indeed, were it not so, there would be no such thing as real progress. In olden times gas wars were sharp and short, but in the newer days the game seems to have dragged; still, it was easier, say 20 years ago, to make a cut from $4 per 1,000 to $3.50 (or even $2.50) than it is now to order a cut from $1.25 to 90 cents. Percentage, perhaps, is that which tells. However, the Brooklyn situation may be thus simplified. The paying of "rent" having ceased, those who received the "rent" must not be cast down if their future income is largely diminished, and some of the moguls who enjoyed its receipt might better attend strictly to the business of selling oil. That was their original business, and their acquired talents ought to fortify them in the knowledge that there is nothing like oil—for them. It is all useless to assert that the Standard Oil Company is back of this Brooklyn row; perhaps people who have a look in at the Standard's business may be concerned in Brooklyn gas securities, but as a Company the Standard's top guns are rather tired of the recoils caused by the gunners in the lower tiers. We do not and never did care much for the methods pursued by Mr. Addicks in the gas field, but common justice prompts the remark that his course so far in the Brooklyn field has been immeasurably above that of his opponents in respect of straight-out dealing; and, in the long run, straight-out dealing wins. To sum it up, between the New York and East River, the Standard, the Williamsburgh and the Fulton-Municipal Companies, the gas rate of New York and Brooklyn will shortly be on a permanent basis of $1 per 1,000. The Jersey City case can be dismissed without much consideration. Over there the gas men have had the field to themselves without molestation, save that that may have emanated from Trenton, but now that Newark has taken a hand in (Newark having been obliged to hold up the price, comparatively, so that its neighbors would not unduly suffer), and that consolidation of the gas interests of Newark and Jersey City is not improbable, Jersey City must come to a reasonable figure.

PUBLIC LIGHTING, CRANFORD, N. J.—The Township Committee of Cranford solicits sealed proposals for lighting the streets of the town with either gas or electricity, on a two years' contract, bids to be opened at 8 P.M., July 9th. Particulars may be obtained by addressing R. C. Plum, Town Clerk.

RESIGNATION OF COL. JOHN T. WHEELWRIGHT.—The following explains itself: "As a law recently enacted forbids any member of the Board of Gas and Electric Light Commissioners from transacting any other business, I hereby resign my office. I have to-day learned from the Secretary of the Commonwealth that this act was approved upon June 21. Had I known on that day that the measure had become a law, I should have at once resigned.—JOHN T. WHEELWRIGHT."

MR. S. G. STINESS TO HEAR FROM HIS FRIENDS.—We have been advised that the Sage of Pawtucket will reach the 30th year of his active connection with the gas business, and the 25th year of his connection with the Pawtucket (R. I.) Gas Company, during the first week of July; and we are also advised that the Guild of Gas Managers, and perhaps the Society of Gas Lighting, of which bodies Mr. Stiness is an active and honored member, will, on July 7th, visit him at Pawtucket, there to fraternally congratulate him on the success which has crowned his long, useful and busy life. Of course, it goes without saying that many others than those who can claim membership in the two Societies named will also join in the fraternal greeting.

ALDERMAN L. E. WYNE has introduced an ordinance in the Kansas City (Mo.) Council which directs that the local gas rate shall be cut to the net figure of $1.18 per 1,000.

[Translated from the *Journal des Usines a Gaz*, by Mr. Herman Poole.]

Mr. A. Crova's Address Before the Association of French Gas Engineers.

Gentlemen:—In agreeing to address you on photometric methods, I have not failed to consider that it is a subject perilous to approach before gentlemen whose occupations impose the necessity of studying the question from the practical side; but perhaps you thought that, having devoted part of my labor of research to the study of luminous radiations, I might summarize in a few words some of the results obtained in that way by the physicists; still as there is often much difference between theory and its application, I hope you will excuse me if you do not find in this short exposition the technical nature which you have the right to exact.

I will pass rapidly over the unit of light. Several years ago you heard Mr. Violle speak of the unit adopted by the Congress of Electricians, and I will simply recall that this unit is, for light that we commonly call white, the quantity of light emitted by a square centimeter of platinum at the temperature of solidification, and for each of the simple lights, the quantity of such light emitted by a like surface under the same conditions. The decimal candle adopted by the Congress of Electricians is the twentieth absolute standard and its value is almost exactly one-tenth (0.96 candle) of a Carcel. The unit, then, is defined physically with much precision, but as it is not the ideal of that which is made use of in the usual photometric determinations, secondary standards become a necessity.

I will not here go over the use of candles of stearin, of paraffine or of spermaceti, long abandoned and condemned beyond appeal; suffice it to say, that under the most favorable conditions these candles give variations in intensity which may exceed 30 per cent. of their value. Other standards, such as the acetate of amyl lamp, the pentane burner and gas flames are subject to causes of error which the Carcel standard lamp adopted in France presents in the smallest degree.

Among the causes of error, I will notice irregular flow of the combustibles in the wick and the instability of flames burning in the open air. The least agitation of the air modifies their burning in such manner that the intensity of the light which they emit varies rapidly between limits occasionally quite large. The flame of the standard Carcel, on the contrary receives automatically an excess of oil and is fixed, so to say, in its glass chimney by a constant draft. It offers hence a fixity and regularity which are far from being attained by any standard burning in the open air.

We must have studied comparatively these last mentioned sources of light with the precision which actually belongs to methods used in physical research in order to appreciate to what extent the Carcel standard shows its superiority.

Employed under conditions closely defined in such remarkable work as that of Dumas and Regnault, and conforming rigorously to the rules laid down by them, it is impossible not to be struck by the facility of comparison and the precision of this standard. An excellent proof of this is given by the remarkable constancy of the ratio of 2.08 existing between the standard of platinum and that of Carcel, which Mr. Violle so exactly established in his work.

Employed in a photometric room with blackened walls, with a temperature of about 60° F., and placed under a hood, in the method described in the directions of Dumas and Regnault, it gives results of great precision.

We know that, within certain limits, the weight of oil consumed is proportional to the light emitted, which permits us under the conditions to refer the light obtained to that which results from the combustion of 42 grammes (648 grains) per hour.

I have placed a Carcel on the pan of a Herve-Mangon register balance, and obtained the fine curves which I show you. You see the proportionality of the consumption of oil to the time, within certain easily realized limits. I hasten to tell you that this regularity requires almost absolute exclusion of air. I placed the standard on the balance pan in the evening, the laboratory was locked, and on the following morning were found the splendid curves which I am showing you. The moment the door is opened a break is found in the curve, which then resumes its regularity. During the day, during the come-and-go of the laboratory, the curve was still less fine. The practical consequence is that the observer must operate in a closed room and prevent all agitation of the air. What do you think, then, will happen when we use flames burning in the open air?

You, gentlemen, who every day have made photometric tests with the apparatus so nicely constructed by Deleuil, know how closely you must observe in common usage the conditions of the temperature, the

humidity of the air, and still other conditions which may be easily appreciated with a little care. In default of these, should you be astonished at certain discordances which are so easily avoided? I do not hesitate to affirm that the French standard is, if not free from all reproach, at least one of the best at present known; but it must needs be remembered that photometric determinations are very delicate, and demand a very careful observer—one who will not neglect the slightest precaution, however trifling it may appear, before making a rigorous observation. It is this way that the illustrious Fresnel, in his photometric researches, would not allow anyone else to prepare the Carcel for him. He regulated it, and he himself cut the wick with the utmost care. Under these conditions it is possible to reach an approximation of a sixtieth, and we may reach that of a hundredth.

This well established, let us pass to the employment of incandesent lamps as standards. The changes which the filament undergoes during use cause slight variations, but nevertheless we obtain illuminating power for the same expenditure of electric energy. This variation, of no account in simple illumination, public or private, prevents the lamp's results being rigorously comparable with each other, and you know that under a good management they must be put one side before they have run the number of hours for which they were designed.

Allow me to speak to you on another subject less known. It has been proposed to reduce to a known ratio the intensity of the flame of a standard by means of diaphragms; that is to say, by limiting its illuminating surface by a screen having a convenient-sized opening. The practice is of a nature permitting many errors. The eye, you know, gentlemen, is a true photographic apparatus, in which the sensitive film is the retina purple, the alteration of which, under the influence of light, is the cause which determines the physiological impression which we call the luminous sensation. This impression has a certain duration and lasts for some time after the light has ceased to act; so that the photometric methods based on the disappearance of interference fringes obtained in polarization photometers, when the two lights have been equalized, are subject to errors hard to avoid. The eye still sees the fringes after they have disappeared and we are carried past the point of equality.

We must shut the eyes for some time, then open them briskly to look into the photometer, regulate anew to cause the fringes to disappear, and begin again the uncertainties. Moreover, the eye becomes fatigued in successive trials, and we are obliged to stop for a while. The use of Foucault's photometer, on the contrary, requires only a glance at a translucent disk. If the eye looks at it for some time the two unequal illuminated portions appear to become the same, and the line of demarcation of the two fields disappears. The same thing happens here as with photography; the contrast of intensity of parts unequally illuminated, however sharp with short exposures, weakens and disappears when we augment the duration of such exposure. It is necessary, then, that the two halves of the photometric disk should be very slightly illuminated and be viewed for only an instant, so as to retain the first impression. My personal experience leads me to think the luminous field of a Carcel of one meter (39.4 inches), as is usually adopted, is much too great, and could be advantageously reduced one-half.

If, then, we fixedly look for some time on a very luminous surface, such as a gas flame or a candle, it appears uniform, and we are led to believe that by diaphragms we could reduce the quantity of light given out in proportion to the surface exposed.

Photography of a flame with long exposure gives same an equally inexact result. But let us reduce the exposure to the neighborhood of the limit of time when all photographic impression ceases; then the concentric envelopes of the flame, which are unequally heated and luminous, appear with an admirable clearness, as you may become convinced by the examination of the photographs I place before you. In the cylindrical burners of the argand type you see the dark axis, and the margin where the envelopes of brisk combustion exist are seen outside, formed of lines, with a marvellous clearness. It is the true anatomy of the flame. In that of a candle, the flame which appears uniform with a long exposure, is reduced by shortened ones to two converging luminous lines in the margin, while the center is obscured. If we photograph, under these restricted conditions, an incandescent lamp, the weak points of the filament, necessarily more luminous by reason of the increased resistance to the current, are shown with an intensity which contrasts with that of the remainder of the filament; and we may indicate with certainty the location of the points where the filament will end by breaking, and thus an easy and certain means of control is given in the careful manufacture of them. In short, it is not solely the positive parts of the arc lamps which appear to the eye and the photograph as made of a uniformly lighted surface, which, when the exposure is reduced to the limit, gives a field which is unequal and varying each moment in points.

We conclude that, in none of the usual sources, is the quantity of flame proportional to the surface which emits it; still more, we change the color. The base of the flame is bluish, for here flows in the air not yet altered by combustion, and the hydrocarbon gases burn blue as in a flame of gas well turned down. At the top the flame is surrounded by the products of the combustion of the lower portions and its temperature is lowered; the flame becomes reddish and sometimes smoky if the draft is not sufficient.

It is necessary, then, when we employ a flame as a photometric standard, to preserve the uniformity of the surfaces of such standard, as well as that of the light with which we compare it. But another difficulty is presented.

The two laws of the square of the distance and the sines of the obliquity, on which are based most of the photometric methods, are true only if the dimension source is reduced to a point.

If the dimensions of the surface of this source are not sufficiently small in relation to their distance from the photometer screen, the law is no longer the same, and, if we use the theoretical formula in calculating the relative intensities of two sources, we become liable to errors, which increase in proportion with that which the greatest linear dimension of the flame bears to that of its distance from the screen.

A very simple calculation will allow us to find the true law in this case; and we may even summarize it practically by saying that a flame may be considered in practice as reduced to a mathematical point when its greatest dimension is less than one-fifth, or more than one-tenth of its distance from the screen. By removing it a considerable distance from the screen, we realize the double advantage of being able to calculate the intensity by the theoretical formulas and of having a faint field which conduces to precise measures.

Before quitting the question of standards of light, I will remark that the general tendency, well founded on what I have just said, is to abandon as standards flames, whether burning in the open air or not, and requiring the combustion of any material, solid, liquid, or gaseous, and to adopt the light emitted by a determined surface of a solid or liquid body, heated to a sufficiently high temperature and maintained perfectly constant. The absolute standard realizes those conditions, since platinum gives them at its temperature of solidification; but it is a phenomenon of very short duration, which must be utilized during the short time when the body passes from the liquid to the solid state. It is, therefore, necessary to have all the resources of a well equipped laboratory and needs a professor accustomed to the work; but it is rigorously definite.

It is not the same with the Schwendler standard, formed of a determined surface of sheet platinum heated to a definite incandescence by a constant and well known current. Independently of the difficulty of assuming the constancy of the current and the dimensions of the sheet platinum, it undergoes a slow alteration which, however brilliant it may be at first, causes it to gradually change and modifies its power of emitting light.

In 1880, I thought of taking as unit of light the quantity of light given out by a square centimeter (.155 sq. in.) of the black surface of an iron vessel in which zinc is heated to ebullition. Here the constancy of temperature may be kept up sufficiently long, but the light emitted is whiter than that given by fixed platinum. Yet, if we observe that, by means of a gas furnace and compressed air, we may easily keep up the ebullition of zinc, we may be induced to believe that, by the use of proper arrangements, this standard could be utilized. Whatever it may be, the question is not yet practically solved, and the physicists should seek for the realization of the usual standard, which ought to be formed of a single determined surface of some solid body with unvariable emitting power, and raised to a temperature which should be very high and perfectly constant.

In the actual state of our knowledge, the Carcel appears to me to be the secondary standard which presents the best guarantees of constancy and comparability; but it is indispensable in precise measures to observe all the directions contained in the teachings of Dumas and Regnault, to operate at a constant temperature of 59.4°, and in an atmosphere perfectly still. We will look at the photometric screen for an instant to assure ourselves that the contiguous images have the same intensity by shutting the eyes during the interval of persistence. It seems well to me to look at it through a convenient shade of green glass which, by weakening the very intense field, assists the eyes in the determinations.

Except in the case of starting new works a very imperfect account, if any, is usually taken of the actual relation existing between the

illuminating power of the gas and the method of manufacture and purifying it; and notably this is so with regard to the temperature and the rapidity of distillation of the coal and similar substances; the longer or shorter duration of the mechanical and chemical purification, the more or less prolonged stay in the gasholder, the distribution, the temperature, the diameter of the pipes, even their caulking more or less perfect, are further causes which may vary the illuminating power. We know to what great degree the admixture of a small quantity of atmospheric air reduces the illuminating power of a gas and how much its diffusion with the air through imperfect joints, or by cracks or porosity in the pipes, may produce the same result.

It is sufficient to mix illuminating gas with 1·20 of its volume of air in order to reduce its illuminating power one-half. Kept in rubber bags, the diffusion with the air through the walls of the bags considerably diminishes its power.

According to H. Sainte-Claire Deville, illuminating gas is not a gas in the acceptation which we habitually give to this term, but a veritable whirlwind of infinitesimal particles of hydrocarbons, solid and liquid, swimming in a gas composed principally of proto-carbide of hydrogen mixed with a variable quantity of hydrogen whose illuminating power is almost nil. We understand how much the influence of time and mechanical actions to which we subject the illuminating gas may amount. It is because of such influences that we must not prolong too much the physical and mechanical purification, from danger of losing a large portion of the illuminating power. The remarkable researches of Leblanc and of Regnault have allowed us to better understand the mode of combustion of a gas, and we may become convinced that one and the same gas may give very valuable quantities of light according to the nature of the burner, the pressure and the kind of combustion. Actually, the demands of consumers, becoming more and more exacting, it is to the interest, particularly in large cities, of the gas makers themselves, to study at the gas works, and at several points along the line of distribution, the effect on the photometric value of rapid increase in day and night consumption, the tests to be repeated at various times of the day. The continued use of the photometer shows the producers the causes which may alter the good qualities of the gas furnished and make them thus prepared for claims and complaints. It permits them also to study the conditions of manufacture, and, by realizing that which gives the best product, to augment the number of consumers and regulate the working of the different methods of lighting.

Illuminating gas is, in fact, a product whose quality may vary between very wide limits, and the nominal power of a burner is subject to great variation according to the circumstance which we have just mentioned. It is the same with electricity, and it has happened often enough that a lamp rated at 10 or 20 candles, or at 100 or 200 Carcels, is found on examination to have a vastly different value from such nominal rating.

The illuminating gas industry, under all its forms, has taken such a development, and the pecuniary interests of those engaged in it are such that only the usual routine practice of photometric operations can assure the correctness of the operations and reduce to their proper value vague and often very exaggerated estimations.

I believe it useless to insist that all outside light should be scrupulously excluded; the reflections of the two lights on neighboring objects are the causes of errors. A photometric measure being represented by a ratio—that is to say, by a fraction—its value changes when we add the same quantity to both its terms.

I will pass rapidly over the photometric methods. You know them well. Their number is considerable, but they have not all the same precision. The methods based on the comparison of the shadows of a rod on a screen, and that of Bunsen (spot photometer), carry with them certain uncertainties of which I cannot speak in the short time allowed to me. It will be sufficient for me to say to you that the method founded on the employment of the Foucault photometer has always appeared to me to be superior in exactness and convenience. When, after short tests, during which we view the disk of the photometer only during very short moments, open the eyes which have been shut some time in order to efface all residual luminous impressions on the retina. If we are unable to see the line of demarcation of the two luminous fields of the photometric disk, we may be quite sure that the two illuminations are equal, and then the least modification given to one or the other of the two sources will cause the line to reappear immediately by establishing a contrast between the two fields.

A different arrangement allows of working the same way in using the relief photometer of Villarceau, of which the essential part is a rectangular prism made of semi-baked porcelain, receiving at the same inclination on the two sides of the rectangle the lights to be compared, and determining the equality of illumination by the disappearance of the edge of the angle which separates the two illuminated fields.

You all know the photometer of Mascart, which serves to determine the quantity of light received on a unit of surface of an illuminated screen by one or more sources of light. The apparatus gives good service in practice. It is furnished with a little secondary standard burning petroleum spirit (naphtha), which is then compared with a Carcel standard, to obtain a measured ratio with the absolute unit, since we know that the unit equals 2.08 Carcels (19.97 candles).

But a new difficulty is presented. While we had to compare lights produced from the usual sources only, and made by combustions sensibly at the same temperature, the tints of the two flames were nearly identical, and the preceding methods were sufficient, since we could easily determine the equality of illumination. New necessities have been caused. The introduction of electric lighting and of intense burners in common practice, substituting, in place of numerous foci of feeble intensity and of sensibly uniform tints, whiter light from powerful burners, or the light from electric sources.

We became accustomed to these brilliant lights, and the gas industry, leaving its ancient traditions, was obliged to compete with the electric light. Then appeared new, more brilliant lights, the use of which is spreading more and more, and of which we try to increase the intensity constantly. This fruitful competition has had the most happy results., and on all sides we are studying to better utilize than ever the previously unknown illuminating power of gas. We are accustomed to intense illuminations, and the consumption of gas has increased in certain cities, spite of, or because of, the use which is made of the electric light. The developments in the direction of heating and the use of gas in motors have been an increasing source of revenue for the works, and they may largely increase even alongside of their redoubtable neighbor. Some works, well intentioned undoubtedly, have furnished their customers, as desired, gas or electricity, and the gas works have become transformed into manufactories of light, heat and motor force, drawn indiscriminately from gas or electricity.

I will state here only two of the new problems which this new state of affairs has imposed on photometry. They are:

1. The comparison of intensities of a Carcel standard and of electric lights of 50 to 200 Carcel power (500 to 1,000 candles) or more.

2. The comparison of two lights of different tints.

These two problems go together, as the power of a jet is obtained generally by a great elevation of temperature of the source of light and not by increasing its surface, as is the case you know with lamps—arc lamps in particular.

When we gradually raise the temperature of a solid refractory body it begins to emit a reddish light; as the temperature increases, more and more; refrangible radiations take birth at the same time with those previously given out and reinforce them. The spectrum increases towards the violet and ultra-violet and the tint changes from red, as in the beginning, more and more white, and finally blue. Do not think, however, that this stage has ever been reached even by the electric light, as its temperature at the positive pole is still far inferior to that of the sun. If we agree arbitrarily, for all in this relation is arbitrary, to say that solar light is white at midday when the sun is sufficiently high, the light of arc lamps is less white and shades towards orange, while that of oil lamps, gas lamps and incandescent ones has a yellow golden tint, and the light of arc lamps only appears of a white tint by contrast. We do not know the temperature of the sun, but it may exceed 5,400°, according to the most probable estimations. That of the arc approaches 5,400°, and that of gas lamps varies from 2,160° to 2,700°; that of the Carcel standard reaches about 1,800. I only mention average values, the temperatures being very unequal in different portions of the flame. How, then, can we compare these different lights, since, if we refer to one same average value by weakening the most powerful by removing it to a distance, one of the halves of the photometer screen will appear of a yellow color by comparison with the other half, which will seem to have a bluish tint by contrast? Further, how can we lessen the power so as to give the same illumination as the Carcel?

The easiest way is to increase the distance from the screen, but with a lamp of 100 Carcels (960 candles) it is necessary to remove it some 33 feet, the Carcel being only 3.3 feet; and then you see what cumbersome dimensions become necessary to give the photometer rooms; above all, if we remember that lamps of 200 to 400 Carcels (1,920 to 3,840 candles) are in quite common use for lighthouse, projector and search lights. Let us say here that we speak of the intensity in a horizontal sense only, and that a complete solution needs the spherical mean also.

All that was to be done, then, was to rearrange so that the Carcel

standard, by reason of its constant value, so easy to regulate under certain definite conditions, and the Foucault photometer, by reason of its sensitiveness and precision, should be retained. The rest could be modified.

We have thought that the intensity of an arc lamp could be determined by means of a standard with the same trial given to a portion of the arc of another lamp, but here we fall into the well known trouble with diaphragmed lamps. Moreover, it was necessary for each lamp, for each temperature of a lamp (for example, incandescent or intensive burner lamps) to have a standard of the same nature, and you see the inextricable confusion resulting from it.

It is true that in two extreme cases the notion of tint or color disappears. The eye proves the sensation of different colors as much as that of intensity of luminosity is comprised between certain limits, but if their intensity is infinitely great, all simple lights give the impression of white. The same is true if the intensity tends towards zero; that is to say, towards the limit where all luminous sensation disappears, all simple lights, of whatever color, give a uniform impression of gray; in the second case, the eye has greater difficulty to determine the equality of illumination because of its feebleness. We must avoid these two extremes.

We may easily eliminate the influence of difference of tint by the following artifice: Let us imagine that we have decomposed the light of the sun with a prism. The illuminating power, feeble in the red, whose vibration length is 740 millionths of a millimeter (0.0000291 inch), increases rapidly to a maximum corresponding to a length of vibration of 564 (0.0000222 inch), which corresponds to a determined green; then it diminishes and more rapidly still as far as the extreme violet.

Let us determine by means of the spectro-photometer this curve of relative illuminating power and make the same for the Carcel lamp. For this lamp the maximum illuminating power is in radiation 592 (0.0000233 inch), which is in the yellow-orange. The total quantities of light given by the two sources are in proportion of the two curves whose abscissas are the lengths of vibration and the ordinates the illuminating powers, and if we diminish proportionally the ordinates of the curve of the sum in such manner that its area shall be equal to that of the Carcel, the intensities will be equal; but these two curves intersect in a point for which the ordinates (that is to say, the intensities) are equal between them and 582 (0.0000229 inch).

Then, if we isolate in the two spectras the light having the length 582 (0.0000229 inch), the ratio of the total intensities of the two sources will be the same as that of these two simple radiations, and all is reduced to a comparison of these two simple lights; that is to say, of exactly the same tint.

But how can we isolate this radiation in the two sources? We do so easily by means of the spectro-photometer; but this is an instrument of research, at once very expensive and very delicate to handle. In practice we must have something simpler. One way consists in adapting to the cone, by means of the opening through which we look at the photometric screen, a little telescope giving a sharp image of the screen, and having in the interior two Nicol prisms, whose principal sections are at an angle of 90° to each other, and having between them a plate of quartz cut perpendicular to the axis and of a determined thickness. By turning slowly one of the Nicol prisms we give the field of view various tints, among which we choose the one which gives exact comparison. But this tint is not that of a simple light; yet the radiation sought dominates in it so much that in the photometer the two tints, very different to the naked eye, appear sufficiently identical to allow comparison as would be made with two lights of exactly the same color. The telescope being adjusted, the observer need not trouble himself about the mechanism. He looks through it and makes his observation in the ordinary manner.

Another way, and simpler, consists in looking at the screen with the naked eye, interposing a cell with parallel faces filled with a solution of chloride of nickel mixed with perchloride of iron in such proportions as will allow to pass only those waves in the neighborhood of greenish-yellow, of a vibration length of 582 (0.0000229 inch), which will allow a close comparison of the intensities.

It will be less accurate to look through a greenish yellow glass of the same apparent tint, since examination by the spectroscope shows that these glasses allow passage to a large number of other waves besides the desired ones, thus rendering it less easy to equalize the tint from the two sources.

All this appears quite complicated at first sight, but in reality, to look with the naked eye through a certain glass or a certain cell containing a certain liquid, is not a great change.

So the Congress of Electricians has decided to recommend the employment of this method, and for some time the officers in charge of the service at Toulon have employed it with much success.

But you will object that this adjustment of the telescope and this solution realizes the equality of color only in the case of the comparison of solar light with that of the Carcel. The same constructions have been made for the Carcel on one part, and on the other for the various common lights, including those of the arc. Without doubt the wave of comparison is found a little different in the last cases, and from a point of view strictly scientific the use of the spectro-photometer is necessary; but in practice, if we take for comparison the mean wave, which we determine by the extreme ones, that of the arc and that of gas, we reach results whose precision is sufficiently great. The color of a source of light, varying with its degree of incandescence, may be very easily determined by means of two photometric determinations made successively. The one made by viewing the screen of the photometer through the cell of which we have just spoken and which allows us to use a greenish yellow of the wave length 582 (0 0000229 inch); the other made with a reddish glass of suboxide of copper which permits radiations between 726 and 574 (0.0000286 and 0.0000226 inch) with a maximum at 650 (0.0000256 inch). The ratio of these two measures allows us to determine the degree of incandescence. It is greater as the whiteness increases. Thus it is equal to unity for sources of the same tint as the Carcel; for the incandescent lamps it varies in my tests from 1.05 to 1.23, according as the lamp was more or less forced; for arc lamps it varies from 1.5 to 1.7, the power absorbed by the lamp being respectively 1,509 and 1,660 watts. The International Congress of Electricians has recommended the use of this method to measure the degree of incandescence or of whiteness of various sources of light and its application to powerful burners, which we find conveniently disposed commonly among consumers of gas, would probably permit a much better record of their relative efficiency.

But still another difficulty exists. We have conquered that which results from a difference of tints, but not that arising from the disproportion between the intensities of the Carcel and that of the intense burners, or still more, that of the 200 to 400 Carcel electric arc lamps, and which would need a development of our photometer rooms to the length of about 100 feet, and the consequent difficulty of managing lamps at such a distance.

This inconvenience may be remedied by the use of properly chosen ground glasses. Let us put, for example, our intense burner in a little annex to an ordinary photometric room and let us receive the light of this lamp on a plate of finely ground glass placed in an opening formed in the closet. If the plate of glass is diaphragmed by a screen furnished with an opening of a square centimeter (0.155 square inches), and if the lamp be placed at a perpendicular distance of one meter (39.37 inches) from the ground glass, this will be in a luminous field of 100 Carcels if the lamp has that power. The little square of ground glass diffuses into the photometric room a light the intensity of which, at unity of distance along the normal, is a fraction easy to determine for the incident light. We might graduate these glasses then in the following manner. A ground glass to be called 100 Carcels if, placed in a luminous field of this intensity, it diffuses normally behind a lamp which at unity of distance is equal exactly to a Carcel. But, then, it is sufficient to make a determination by placing at equal photometric distances at one meter (39.37 inches), the Carcel on one side and the ground glass on the other; the two lights are reduced to being comparable but must be equalized.

To do this, replace the screen with an opening of one square centimeter (0.155 inch), by another whose opening variable at will may be measured by a micrometric scale. We obtain thus rapidly equality of intensity. Here it is legitimate to diaphragm, because if the lamp is at a sufficiently great distance, 1 meter (39.37 inches), for example, from the open air of the ground glass, if it is sufficiently small, a half centimeter (0.197 inch) to two centimeters (0.787 inch) square, is confounded in these small limits with the spherical surface of a meter (39.37 inches) of radius, which constitutes the luminous field of constant intensity, and hence has the same brightness at all its points. The quantity of light that it emits is then proportional to its free surface. Let us suppose that in using a ground glass of 100 Carcels it was necessary to give it an opening of two square centimeters (0.31 square inch) in order to have the same illumination as that provided by a Carcel at the same distance, a square centimeter (0.155 square inch) would give one-half as much, and as the glass is a 100 Carcel one the intensity would be 50 Carcels.

The only difficulty remains in the graduation of the glasses, which cannot be done outside of a laboratory well equipped and developed. But such glasses could be made by a regular instrument maker. It

must be remembered that there is nothing so easily altered as a disk of ground glass, and that the least film or impurity alters its diffusing power; but we may cover the ground glass portion with a thin piece of glass which does not touch it, being separated by a thickness of paper pasted around the border and sealed on the edges with mastic, and kept in a little brass box. Thus prepared the ground glass is unalterable, and keeps indefinitely the same diffusive power.

In closing, gentlemen, you see that the difficulties inherent to the employment of new and very powerful light sources, and of different tints, are resolved exactly by scientific methods applicable solely in well equipped laboratories, and with a sufficiently close approximation for technical use by the arrangements of which I have just spoken.

The Pneumatic Pyrometer.

By Mr. Edward A. Uehling, in the *Stevens Indicator*.

The want of an accurate, reliable, and durable instrument for measuring high temperatures has long been felt, not only by scientists, but by engineers and metallurgists as well.

The pyrometers which have so far been available have either proved to be too delicate and difficult to manipulate for practical use, as, for instance, is the case with the electrical instruments, or inaccurate and reliable, as are those depending on the expansion of metal rods, or too inconvenient and cumbersome, as are those depending on calorimetric methods.

The air pyrometer, although based upon the substance which possesses the ideal properties required for measuring the widest range of temperature with the greatest accuracy, has thus far given reliable results only in the hands of physicists.

It is not the object of this article to discuss the shortcomings and errors of the existing pyrometers; but, rather, to describe a new instrument, which is based on the fundamental laws of the flow of air, and makes use of a novel principle, by the aid of which all the difficulties attending the use of the existing air pyrometers are overcome.

The pneumatic pyrometer, which is the invention of the author, and has been brought to its present degree of perfection by Mr. Alfred Steinbart, a graduate of the University of Berlin, Germany, is based on the novel application of the law of flow of a perfect gas through two successive minute apertures. If these apertures form respectively the inlet and outlet of a chamber, then the tension in the chamber depends upon the difference of temperature at which the air flows through the respective apertures into and out of the chamber.

Thus, if a current of air be caused to flow through the chamber by a constant suction, and be allowed to enter at one aperture at the temperature to be measured and be exhausted at the other at a constant normal temperature, then the tension of the air in the chamber will be a correct indication of the temperature to be determined.

The accompanying illustration represents the application of this principle to a pyrometer designed especially for continuously indicating the temperature of the blast used in the smelting of iron. The universal blast furnace practice now is to heat the blast to from 1,200° to 1,600° F., and it is very important to know at all times what the temperature of the blast is.

The principal object in using a highly heated blast is to economize fuel; but the temperature of the blast also affects the chemical composition, and hence the quality of the iron produced. Variation in the temperature of the blast, therefore, not only tends to increase the fuel consumption, but to prejudicially affect the quality of the iron, as well.

All modern blast furnaces are now equipped with firebrick stoves for heating the blast, and the everyday practice is to "change stoves" on time, usually at intervals of one hour. As a rule, at all well managed plants, the temperature is taken with some form of portable pyrometer by the "stove men" at every change of the stoves, and recorded. The founder, however, has little faith in the record, and pays no atttention to it. If the blow pipes show red he knows he has a good heat; if they are bright red the heat is very good; and, if the pipes are dark he stirs up the stove man, and if the furnace has made an "off-cast" of iron in consequence, the stove man is more or less severely hauled over the coals. "The heat was all right; see the records, 1,300° to 1,450°." "D—— the record! Black blow pipes and white iron show what your heat was. You did not have 1,000°. I want 1,500°." The "stove man" now puts his entire energy into getting the heat up. Probably, when the founder comes around again he finds the blow pipes white hot. His experience prompts him to inspect the stoves. He finds the combustion chambers dripping with the molten firebrick. "What do you mean by melting down the stoves?" "You wanted 1,500°, and I tried to get it." "Why, you have 1,700° to 1,800°." "No, sir; I have only 1,480°; I just tried it." "White-hot blow pipes and melting down stoves on 1,480°? Nonsense!" "But the pyrometer shows 1,480°, and that is all I have to go by, and they want a record of the heat in the office." "That's all right enough for the office, but in future you watch the blow pipes and the combustion chambers, and don't pay any attention to the pyrometer when I give you orders."

This illustrates the state of the art as applied to blast furnace practice; and other industries using high heats fare no better, if not worse. Confining ourselves to the blast furnace, we have the fact that 100° of heat carried in by the blast is equivalent to something like 50 pounds of fuel per ton of iron filled at the top. Assuming the cost of coke at $2.50 per ton at furnace, and the average output at 150 tons per day, 100° of heat in the blast would mean $\frac{2.50 \times 50}{2,000} = 6\frac{1}{4}$ cents per ton, or $9.32 per day, or over $2,500 a year. The difference in the market price between No. 1 and No. 3 foundry iron is about $1. Supposing the furnace makes only 50 tons of No. 3 iron, on account of irregular heat in blast, in a week, this would amount to 50 × 52 = $2,600 a year. Both together, therefore, foot up to over $5,000, or 10 times the cost of an instrument such as illustrated and described below.

At the No. 2 furnace of the Sloss Iron and Steel Company, where the pneumatic pyrometer has now been in constant use for over four months, the following facts were revealed:

First. That no two stoves gave the same results, the best one losing 250° in one hour, and the worst one the same amount in 35 minutes, and that changing by the watch at intervals, every hour for instance, as is the usual practice, must give very irregular results.

Second. That while the records of temperature taken in the usual way varied between 1,350 and 1,450°, the actual variation was between 1,150 and 1,650°.

Third. That a dark blowpipe is not always an indication of low temperature. The pipe may be coated on the inside and indicate much less than the actual temperature of the blast.

Fourth. That the best portable pyrometers now available will vary from 50 to 150° above or below the actual temperature measured.

Fifth. That with four good stoves the temperature of blast may be kept within 50° of the heat desired.

Sixth. A dirty stove or a "short cut" in a stove is at once revealed by the incapacity of the latter for holding the heat.

It is, therefore, probably underrating the benefits derivable from the use of an accurate and continuous pyrometer to base its value on the figures given above.

The pneumatic pyrometer, as illustrated, is shown as attached to the hot blast main of a blast furnace, and is especially designed for that purpose. It consists of a platinum tube B^3, Figs. 2 and 3, half an inch in diameter, and of sufficient length to extend very nearly through the lining of the hot blast main, to the shell of which it is secured by the coupling *a*, and the gland *b*, the latter being secured to the flange *c*, which is bolted to the shell. Concentric, within the tube B^3, is placed a smaller platinum tube, $e\,e^1$, $\frac{5}{16}$ of an inch in diameter, which extends very close to the end of the tube B^3, and is held in position by the coupling *f*. The connection between *a* and *f* is provided with a branch *h*, to which is connected a filter B^1. The latter consists of a chamber about 2 inches in diameter and 10 inches long, loosely filled with cotton. The inner pipe $e\,e^1$ continues by the pipe *i i* to the vessel *C*, and within this by the pipe *j* and worm *k k* to the coupling C^1, which is shown in detail, Fig. 4. The first small aperture is located at the end e^1 of the inner tube $e\,e^1$, and the second aperture is located in the coupling C^1, as shown in Fig. 4 at *l*. From C^1 the tube continues by *m m* to the top of the chamber *A*. *A* also connects with an aspirator (not shown) by the pipe *n n*, and with the manometer *q q* by the bent tube *o;* it is further provided with a stopcock *p* and with a tube *r r* which is open to the atmosphere at the upper end and reaches to within 3 inches of the bottom of the chamber *A*. The upper end of *r r* passes through a stuffing box and is provided with a rack and pinion and wheel *s*, by which it may be raised or lowered. The pipe *i i* communicates through the capillary tube *t t t* with the manometer *u u* and may be prolonged by means of a T-piece *v* and tube *w* to the office, or any other place or places where it may be necessary or desirable to indicate the temperatures to be measured. The manometer tubes *q q* and *u u* have their lower ends immersed in colored water, contained in the reservoir *R*. The vessels *A* and *C*, which are made of brass tubes 7 inches in diameter, are respectively 4 feet 8 inches and 1 foot 6 inches long, are connected with the water supply pipe by the pipe connection *E F T* and *E S N*. *C* is the temperature regulator, and, with the valve *K* closed and *L* and *I* open, is kept filled with water to the level of the overflow *H*. The pipe and worm *x y z*, which is connected with the steam or hot air main, continually keeps the water boiling; and, because *C* is open to the atmosphere through *D*, a constant temperature of 212° F. is maintained. *A*

is the suction regulator. By opening the petcock *p* and the valve *M* it is filled with water to the proper level. The tube *r r* must be immersed in the water in *A* exactly 4 feet, which can be readily done by the wheel *S*. By these means the essentials for exact determination of temperatures are supplied. The aspirator, capable of exhausting a somewhat greater volume of air than the small apertures will admit, is turned on; and the deficiency being supplied through the tube *r r* against a constant head of 4 feet of water, the suction at C^1, the second aperture, cannot vary appreciably above or below that point. By the manometer *q q* the suction may be at any moment observed, and will be found standing steadily at the point 4, so long as the tube *r r* extends into the water the proper depth.

The water in *A* very gradually evaporates, and as this occurs to an appreciable amount *r r* is lowered; when it has reached the bottom, it is again raised, and the waste is supplied through the valve *M*. This, in continual use, is found necessary about once a month.

The suction being applied, the air from the atmosphere enters through the filter B^1, where it is freed from dust, flows through *h* into the platinum tube B^2, where it assumes the temperature of the hot blast in the main *B*, at which temperature it enters the first aperture e^1 at the end of the tube, by which it returns and passes through *i i* into *j* and the worm *k k* located in the boiling water maintained in *C*. The temperature of melting ice, or any other constant temperature, would answer as well. In its passage through the worm it assumes the constant normal temperature at which it flows through the second aperture located in C^1, as

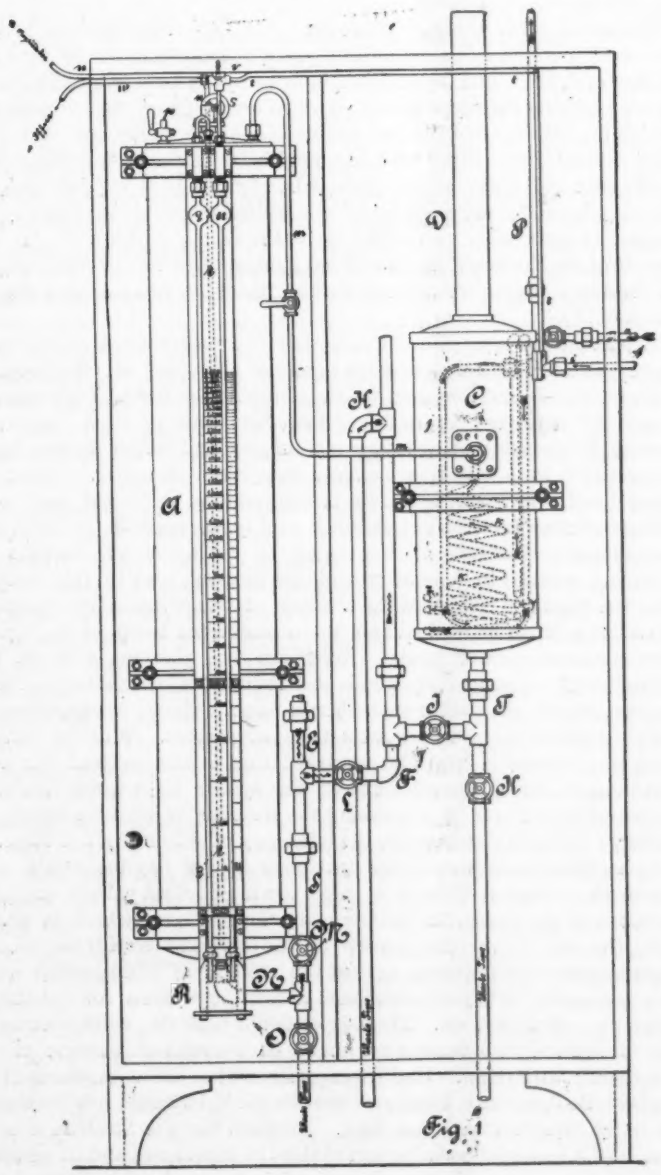

Fig. 1.

shown in the detailed sectional cut, Fig. 4, thence through *m m* into the regulator *A*, and from it, by the pipe *n n*, to the aspirator.

As already explained, the tension in the chamber or tube between the two apertures is a correct measure of the difference of temperature at which the air flows through each of them respectively; therefore the manometer *u u*, supplied with proper index, and connected to the tube *i i* by the capillary tube *t t t*, will continuously and accurately indicate the temperature in *B*. The temperature manifesting itself as tension of a ***continuous current*** of air through *i i*, *j*, *k k*, the length of the capillary tube *t t t* does not affect the accuracy of the indications, neither does the number of manometers connected, so long as the connections are perfectly air tight.

It is therefore quite feasible to indicate the temperature in as many places as may be desirable.

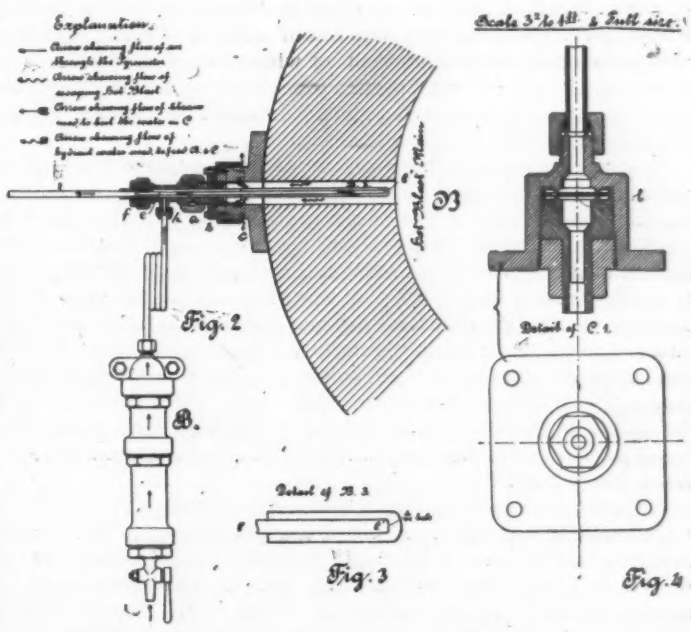

Fig. 2. Fig. 3. Fig. 4.

It is also immaterial, so far as the accuracy of the indications is concerned, at what distance from the place at which the temperature is to be measured the tension and temperature regulators *A* and *C* are located, so long as the area of the tube between the two apertures is sufficiently in excess of the area of the apertures. The latter is only $\frac{1}{64}$ of an inch in diameter, and can be made even less; and ⅜-inch pipe is ample for distances below 500 feet.

The pneumatic pyrometer can therefore readily be made semi-portable. By making the tube *i i* of sufficient length and flexibility, it would be quite feasible to transfer it from the smoke box to the furnace or into any portion of a flue of a boiler which may be undergoing a test.

Changes of temperature of the air in the conduit between the apertures affect the accuracy of the indications only momentarily. By virtue of the continuous flow of the air through the tube, equilibrium is very soon established, and then the difference of temperature at which the air flows through the respective apertures determines the tension irrespective of its temperature while flowing from one aperture to the other. This property renders the pneumatic pyrometer available for measuring the temperature of very small areas as well as large ones; for instance, it is just as feasible to measure with it the temperature of the contents of a 10-gramme crucible as of 40 tons of molten steel contained in a huge ladle, and it can be made to indicate the temperature of the flame of a Bunsen burner as accurately as heat of the flame issuing from a converter.

The term, pyrometer, when applied to the above described instrument, is really a misnomer, for while it is capable of measuring temperatures up to where platinum ceases to be a solid, its range for low temperatures terminates only where air ceases to be a perfect gas. Its telemetric properties would seem to render it particularly applicable to cold storage plants, and to all other industries where it is important to know the temperature of a place without going into it. The most important effect of the telemetric feature of this instrument will manifest itself in the moral force which it exerts on those who have to be relied upon to maintain the necessary or desired temperatures. It is one thing to give instructions that certain temperatures shall be maintained, and another to know that the orders are executed. If you have the means of knowing whether your orders have been faithfully carried out, they generally will be carried out, and ***vice versa***.

One of the above described pyrometers has now been in continuous use for over four months, and has in that time frequently been subjected to heats above 2,000°, and on one occasion to over 2,700° without affecting its sensitiveness at the ordinary temperatures—viz., 1,200 to 1,600°.

Power Distribution by Electricity, Water, and Gas.

[Abstract of a paper read by Mr. E. C. de Segundo, before the English Society of Engineers.]

Briefly stated, the paper was devoted to the consideration of: (1) The efficiency of electric generating plant in central stations at the present day. (2) The efficiency of power producing plant in hydraulic power stations. (3) The efficiency of gas engines for the production of power. As the motors dealt with were all heat machines, the author based his comparisons on the ratio of the thermal equivalent of useful work available for commercial purposes to the calorific value of the fuel burnt per hour; and he pointed out that such considerations as cost of fuel could easily be applied after. Having given his reasons for adopting this basis for comparison, Mr. Segundo proceeded—

A steam engine is usually accounted an extremely wasteful heat machine; but this is, strictly speaking, not the case. The only way to increase the efficiency of the steam engine is by lowering the lower limit of temperature; but directly efforts are made in this direction, a limit is soon reached beyond which further lowering of the temperature not only ceases to be productive of any good, but is productive of evil. In short, it may be said that all the heat developed in the combustion of fuel is utilized by the steam engine, either in doing work or in providing the means of doing work, or controlling the rate at which work is done: The efficiency of the steam engine and boiler combined is not difficult to determine; it is the ratio of the thermal value of the brake horse power hour to the calorific value of the fuel consumed per brake horse power hour.

The efficiency of the gas engine and its equivalent of steam boiler requires some investigation. A ton of coal, according to Mr. Emerson Dowson, may be taken to produce 9,500 cubic feet of gas and 1,500 lbs. of coke, of which about 400 lbs. will be consumed under the retort. Assuming that coal having a calorific value of 14,000 thermal units per pound is used, and taking the calorific value of coke at 10,000 thermal units, the number of thermal units liberated from 1 ton of coal is (neglecting the heat necessary to raise the mass of coal to the temperature of the retort), $2,240 \times 14,000 - 1,500 \times 10,000$, or 16,360,000 thermal units. Of the heat developed by the consumption of the coke under the retort, a large proportion can never be expected to reappear in the gas. But 16,360,000 thermal units have actually disappeared in producing 9,500 cubic feet of gas; hence, $\frac{16,360,000}{9,500}$ or 1,722 thermal units should be accounted for per cubic foot of gas.

Professor Kennedy, Professor Unwin, and others have made calculations as to the calorific value of a cubic foot of gas, the results of which agree fairly. The average calorific value of London gas may be taken as 620 thermal units per cubic foot at 55° F., and at a pressure of 14.7 lbs. per square inch; hence the efficiency of the gas generator (one might call it) is $\frac{620}{1,722}$ = about 35 per cent.

The function of a steam boiler is, in the case of the gas engine, split up into two; one portion is done at the gas works, and the remainder in the cylinder of the engine itself. Now about 24 per cent. of the heat given to a gas engine is turned into indicated power, or in the case of a large sized engine about 20 per cent. is converted into brake horse power. Hence the real efficiency of the gas engine and boiler, so to speak, is about 7 per cent. The efficiency of a non-condensing steam engine, consuming 2 lbs. of coal of a calorific value of 14,500 thermal units, and working at 80 per cent. mechanical efficiency, is 8.72 per cent.; so that the total efficiency of one machine is very much the same as that of the other on this basis of argument. But Mr. Dowson claims to produce one brake horse power hour for 1 lb. of anthracite, by using his generator gas. This (taking the calorific value of anthracite at 16,000 thermal units per pound) would correspond to a total efficiency of nearly 20 per cent.—an efficiency which the steam engine and boiler can never hope to reach.

Although the author desires to consider the two heat machines on the basis of what may be termed the useful efficiency—viz., the ratio of available power or brake power to power equivalent of fuel burnt, still, in the face of so great a difference as the foregoing, it may be of interest to inquire into the reason of the difference. To do this, it is necessary to consider another efficiency—viz., the ratio of heat turned into work in the cylinder to the maximum theoretically possible. This latter quantity is expressed by Carnot's law as the ratio of the difference of temperature at which heat is received and rejected to the absolute temperature at which the heat is received. In the case of the steam engine, this ratio is not difficult to determine, because the heat is all received at one temperature and rejected at one temperature. But in the case of the gas engine this is not so. As mentioned before, part of the function of the boiler, or part of the operation of calling into existence the working fluid whereby heat energy may be transformed into mechanical energy, is performed in the cylinder of the engine itself. This operation cannot be instantaneous, in obedience to physical laws, and therefore the heat is received during an appreciable interval of time, and at temperatures varying from the temperature of the mixture at the end of compression to the maximum temperature reached by the charge after explosion. In some parts of the cylinder, this temperature may, according to Mr. Clerk, be as high as 3,400° F. It would appear, however, that most authorities agree upon 2,700° F. as about the maximum temperature reached by the charge in gas engines of all forms. The temperature of the discharged products is not far short of 800° F., though, of course, the heat rejected is not rejected at one temperature. Hence the maximum efficiency attainable should be $\frac{2,700-800}{3,160} = \frac{1,900}{3,160} = 60$ per cent.

The efficiency of the non-condensing steam engine cylinder under admission pressure of 130 pounds per square inch and an exhaust pressure of 20 lbs. per square inch, would be about 18 per cent. Therefore if this steam engine turns 8 per cent. of the heat into work, it is doing as well relatively to its peculiar limitations as the gas engine that turns 26 per cent. of the total heat received into work. The greater useful efficiency of the gas engine therefore must be ascribed to the nature of the vehicle used for carrying the heat, and not to the superiority of the gas engine as a heat machine.

The great faults of a gas engine are: (1) The enormous heat lost in the cooling effects of the cylinder jackets, sometimes over 50 per cent. of the total heat; and (2) the high temperature of the exhaust products. It is not within the scope of this paper to even suggest any direction in which the efficiency of the gas engine might be enhanced; but it is obvious that, if the link could be forged between the now disconnected heat chain in the gas engine cycle, whereby the heat carried away in keeping down the temperature of the cylinder could be usefully expended in some other part of the cycle, the time would not be far distant that Sir Frederick Bramwell has spoken of, when all that remains of the steam engine would be a working model or two in some obscure museum.

Attention was next directed to electric generating plant using steam power, and the author gave some practical examples of efficiencies of such plant. Discussing next the distribution of power by high pressure water, he expressed the opinion that for working lifts, cranes, or presses, it was doubtful whether any simpler and better means could be provided in a city like London than water pressure. If, on the other hand, the form in which the power was delivered had to be changed before it could be applied, it was quite possible, he said, that the efficiency of transformation might be so low as to dissipate the economy attained in generation and distribution; and in this connection Mr. Segundo compared the number of transformations necessary to enable a lift to be worked and an incandescent lamp to be lighted from a central power house. Reference was also made to M. Van Rysselbergh's system of hydraulic distribution in generating electrical energy, which, the author said, should enable electrical energy to be sold at considerably cheaper rates than at present. Without dealing with this scheme in detail, he remarked that it was evident the only directions in which the efficiency of the system as a whole could be increased were: (1) By decreasing the number of transformations of energy; and (2) by increasing the efficiency of either or all of these.

Considering next how power produced by gas engines could meet the needs in electric light in a large town provided with a complete network of gas mains, the author said: In this case (which is practically the case of every large town in the civilized world) the electric light comes as a competitor against the method of illumination which has practically only just established a firm reputation for reliability, economy, efficiency, etc. There is no doubt that the conveniences of gas for lighting and heating are apt to be overlooked because of our familiarity with them. Had we experienced the inconveniences of oil and candle light only, I feel sure the electric light would not have made so much progress as it has done. Further, the gas business is in the hands of a powerful body, powerful alike in experience and in resource.

Experience of practical working in London and other large towns shows that, in certain districts and under certain conditions, there is a sufficient demand for the electric light to make it worth while to work independently of the gas company altogether. But consider the very vast majority of country towns already supplied with gas, where it is obvious that an independent electric light company would eke out a very miserable existence, and that probably for only a short time, it

would certainly seem reasonable that a combination of electric light and gas interests would solve the problem of electric supply to the inhabitants; and if this is so, then the principle ought to apply, *a fortiori*, to large towns. At present these interests conflict, and it is universally experienced that someone has to pay for this.

Let us try and examine this a little more closely. If electric light and gas interests harmonize, the first advantage that suggests itself is the ready made central station—viz., the gas works. It is then necessary to establish distributing stations at suitable points in the town. Each distributing station would consist of gas engines and dynamos and regulating apparatus. Each distributing station would supply its own network of mains for the needs of its own neighborhood. These networks would have to be connected by a trunk main, so that any one station could be relieved by any other in case of emergency, and during the period of light load. The details of the plant of each station and the number of stations would be dictated by local conditions, so that it is impossible to do more than state the broad principles. As there would be no boilers, no chimney stack would be required. Probably in nine cases out of ten, the basement of some house could be adapted to accommodate the necessary plant; hence a great saving would be effected in special buildings. Further, the labor required would be diminished. The cost of superintendence would probably remain the same, but might be increased.

Now as to the cost per unit delivered. There is fortunately not much difficulty in determining this, as many examples of the generation of electrical energy by gas power now exist. The author has selected the results of the weekly records of a plant at Bradford supplying 300 lamps. The total cost per kilowatt hour delivered is almost exactly 2d., with town gas at 3s. 3d. per 1,000 cubic feet.

But to adapt this to a distributing station 5 per cent. should be added for loss in mains, and 0.3d. per kilowatt hour for depreciation in plant and buildings. This would bring the cost to 2.4d. Adding the very liberal allowance of 0.6d. per kilowatt hour for management expenses, the total cost would amount to 3d. per kilowatt hour delivered. This is a lower figure than that usually realized in practice by any purely electric supply company working under the conditions above assumed; and no doubt this aspect of public electric supply has for some reason or other not received the attention it deserves. In order that the two systems (direct use of gas and, what may be termed, gaso-electric) may be commercially equivalent, the cost of maintenance of the plant, the interest and depreciation and management expenses must be compensated for by the economy in gas consumed.

Now it is frequently thought that nothing can be more economical than the system of sending the gas direct to the burner. But this is far from being true. The miserably low efficiency of the gas burners is rarely appreciated at its true value. According to Professor Tyndall, the efficiency of the gas burner is 0.317 per cent. Taking the calorific value of the London gas at 620 thermal units per cubic foot, only the equivalent of 10 thermal units reappear as light out of a possible 3,100 thermal units in a 5-foot burner. When gas is utilized to produce motive power, its efficiency and that of the incandescent lamp is so superior that a very different result is obtained. The efficiency of a 16-candle power incandescent lamp being about 6 per cent., and assuming a mechanical efficiency of 80 per cent. for the gas engines and 85 per cent. for the dynamos, including loss in transmission, it is found that about 25 thermal units would reappear as a light out of a possible 3,100. So that in spite of the three-fold transformation of energy introduced, the final result is increased 2.5 times. This ratio would, of course, be still further increased in the case of arc lamps. The value of these ratios, taking minimum values in the cases of electric generation by gas engine power, are as follows:

Character of Burner.		Percentage Increase of Candle Power Obtainable by Using a Gas Engine to Drive a Dynamo Supplying Electric Lamps, as Compared with that Obtained by Burning the Gas Direct.
Gas.	Electricity.	
A good ordinary 5-ft. gas burner, such as a "Bengel" burner.	An incandescent electric lamp, using 4 watts per candle, and giving 16 candle power.	Per Cent. 78
A Wenham lamp.	An arc electric lamp of the same power as a Wenham gas lamp.	227

The reason of this is that the chemical combustion of coal gas with oxygen yields a flame in which the undulatory vibrations of sufficient frequency to become luminous are extremely few compared with the heat waves; whereas, in a gas engine it is these heat waves that are transformed into mechanical energy.

The chief points of a gaso-electric system of distribution may be summed up as follows: (1) The generating station already exists, and may be considered as an electric power house. (2) The existing gas mains available, hence there is no question of a separate main network being laid as in the case of hydro—or æro—electric supply. (3) The useful efficiency of gas is out of all proportion greater when utilized as a motive power than when burnt direct in burners; and this, in spite of the extra transformations of energy introduced. (4) It is more than probable that, under a system such as has been discussed above, the cost of maintenance, superintendence, and management expenses will be less than under conditions of independent electric supply. (5) By paving the way for the substitution of electric for gas lighting without conflict of existing interests, an incalculable benefit is conferred on the community.

In the concluding portion of the paper, the author observed that, of course, the hydro-electric system may be treated from the same point of view if once hydraulic supply mains exist. But the present efficiency and character of high pressure water motors do not suggest the possibility of any very great economy being effected. It must not be forgotten than Van Rysselbergh's claim to economy is based upon a motor efficiency of 80 per cent., which, though not unattainable is very high, and could not be relied on as an average result in practice. But for large private installations, the energy supplied by the hydraulic power company could be utilized with advantage.

SPECIAL ENGLISH CORRESPONDENCE.

COMMUNICATED BY NORTON H. HUMPHRYS.

SALISBURY, June 10, 1894.

Enriching Gas.—Gas from Tar.—Quality and Price of Gas.—Gas Engines Shown to be the Cheapest Way of Generating Electric Light.

Perhaps the most notable event of the year 1894, from our special point of view, is the attention that is being devoted to enriching processes. It should be explained that a very large proportion of our English gas coals do not yield a gas of over 15 candle power, and, therefore, that in order to pass the standard of 16 candles, which is now usually insisted on, the use of cannel or some other enricher must be resorted to. The supply of ordinary or unenriched gas, of a quality that might be depended upon to pass a standard of 14 candles, is finding such powerful advocates as Mr. George Livesey and Prof. Lewes, but the opinion of the majority is in favor of supplying a good article and keeping up the quality to 17 or 18 candles, in view of the competition, not so much of electricity, as of cheap petroleums. Hitherto cannel has answered every requirement. But the necessary cost of this material, on the one hand, and the supply of various fluid hydrocarbons at moderate and even low prices, on the other, together with the increased cost of coal and labor, which renders it necessary to be on the alert for every possible economy, are responsible for the present activity. At the recent meeting of the Institution of Gas Engineers, Mr. J. F. Bell, of Stafford, described a simple arrangement he had adopted for raising the quality of his gas from 15 to about 18 candles, by means of any fluid hydrocarbon that is sufficiently volatile to be vaporized by steam heat. In the course of this paper it transpired that Mr. Bell has made a move in the direction of supplying two qualities of gas from one system of mains. During the hours of daylight he supplied 15 candle or unenriched gas, but a supply of 18 candle gas is turned on an hour or so before dusk and maintained till after midnight. Mr. Bell can, therefore, deal with the light oil obtained by the distillation of coal tar, if prices render such a course advisable. Mr. S. Glover, of St. Helens, described his practical experience in adopting Young's, or, as it is more generally called, the Peebles process, and Mr. R. Herring followed with the results of eight months working with the Tatham, or oxy-oil process, at Huddersfield.

The forthcoming meeting of the Gas Institute follows the example of its newly fledged competitor in having three papers treating of this subject. Mr. H. Ashton Hill, of Wallasey, in a paper on "Gas Manufactures," will refer specially to enrichment by cannel, and it is well, amid the glamor of new ideas, that the old plans should not be forgotten. Mr. J. Stelfox, of Belfast, will treat of a first season's experience with carbureted water gas, and a special interest attaches to this paper because it is known that one of the reasons for introducing this process at Belfast was the prospect of getting a larger production of gas on the

same area of ground, the facilities for obtaining room for extensions being apparently in a considerably less ratio than the increase in the demand for gas. And Mr. C. S. Ellery, of Bath, will deal with the production of gas from tar.

This topic is especially interesting at the present time, when the price realizable for tar is merely trifling—some works which happen to be at a distance from the tar distillers do not net one cent per gallon for it. Besides these, it is also known that Messrs. Humphrys & Glasgow are busy at work flavoring up the Lowe water gas process to suit English ideas.

The current issue of the *Journal of Gas Lighting* contains an account of some experiments made in the way of utilizing tar, by Mr. J. Smith, of Bangor, and the results of a practical trial, certified by a subcommittee specially appointed to investigate the matter, are surprising. One ton of tar is reported as yielding 9,700 cubic feet of gas, 8 cwt. coke and sufficient oil to replace about 2½ tons of coke as fuel. So we must look more respectfully at the 200 gallon tank load of tar as it passes out of our works, for its intrinsic value is more than that of the ton of coal that is just coming in, and for which we have paid about double the price. Mr. Smith's original idea was to completely reduce the tar to coke or gas. He ran a small stream of the liquid into an iron retort set in the usual way, and proposed to return the oil that collected in the hydraulic to the retort. But he was unable, at the highest temperature possible with the iron retort, to gasify the whole of the liquid, and the residue that remained was turned to account as a fuel under the retorts. Taking the weight of the gas (the quality of which is not stated) at 3 cwt., the heating value of the residual oil would be more than five times that of coke. It would be interesting to have further details as to the kind of coal and the other circumstances under which this tar was produced. If Mr. Smith can really add about another 1,000 cubic feet to the production per ton of coal carbonized, and yet have residuals that are worth more than the tar as produced in the ordinary way, he certainly has effected a great advance.

But there is some anomaly in suggesting the gasification of tar. It seems more reasonable to suppose that, rather than allow the tar to condense, and then to re-vaporize it, the more direct way is to deal with the vapors as they leave the retort in the first place, after the manner adopted in the Dinsmore process. If the tar must be liquefied first in order to separate it from the permanent gas, why should it not be fractionated, the heavier parts being taken away, and the lighter parts only returned to the retort. It must be a waste of fuel at the least, to heat up matters that simply condense again.

Amidst all this activity, the question of quality, as compared with price, is one that must not be overlooked. People want cheap gas. The users of gas engines, gas stoves, or other appliances that depend upon the heat afforded by the gas, look at price rather than illuminating power, because a gas of 15 is practically of the same value to them as a gas of 20 candle power. The same may be said of the users of incandescent burners. It is the flat flame burner that creates the demand for high power gas, because it fails to develop the full value from low power gases. With a 20 candle gas, the duty yielded by the flat flame burner is equal to that of the argand. But with a 15 candle gas, the flat flame only gives an equivalent of about 12. Looking at the fact that the greater part of the gas used throughout the kingdom for lighting purposes is burnt in flat flame burners, it follows that there is a demand for high power gas, even at a more than proportionate advance in price. But here another question comes in. High power gas, especially if enriched, requires careful burning to avoid smoking and "blacks," and the result is that in districts supplied with gas of this grade smaller burners are used, and instead of losing by way of the flat flame, the consumer loses by the difference of the duty afforded by small as compared with larger burners. It is only another way of killing the cat. Then we find that a large section of the public advocates gas of as high a power as possible on what they call sanitary grounds. This argument finds favor with medical and scientific people, who consider that the higher the quality the less the degree of vitiation of the atmosphere, as a lesser quality of gas will produce the same lighting equivalent. The problem is complicated by changes that are being made in the value of many of the factors. With improvements in incandescent and regenerator burners, and the increased use of gas for purposes other than lighting, the power of the flat flame party is continually decreasing. On the other hand, whereas we were accustomed to regard each candle over 16 as adding about 1½d. to the cost of the gas—that is in London and throughout the south of England—we are now told that as much can be done either with the Peebles or the oxy-oil process for less than ½d. With regard to vitiation of the atmosphere, the latest researches seem to show that, given a proper degree of ventilation, the air must be changed so rapidly as to put the question of a few cubic feet of gas per hour, more or less, entirely out of court. Amidst so many conflicting matters, the only way is to wait and see what time will bring forth, because a verdict arrived at to-day may be entirely upset to-morrow.

A very interesting and important paper on the distribution of power by electricity, water and gas, by Mr. E. C. de Segundo, was read before the Society of Engineers a few days ago, in the course of which the author goes fully into the cost of generating and distributing power by means of electricity as practiced for the supply of electric light, of effecting the same purpose by means of hydraulic power generated at a central station, and of utilizing the existing gas mains by the use of gas engines on the spot. In considering the theoretical efficiency of a gas engine the author carries his investigation a step further than usual and goes back to the original coal. Comparing the gas engine with the steam engine, as regards coal used in the first place, he arrives at 7 per cent. for the gas engine and 8.7 for the steam engine. He calculates that 1,722 units of heat disappear in the production of a cubic foot of gas, of which only about one-third, or 620 units, are obtained by the combustion of the same. But he reckons nothing for the tar, credits coke with a combustible value of only 10,000 units per pound, and allows only 9,500 cubic feet for the yield of a ton of coal. Now, in ordinary practice, we expect to *sell* 10,000 cubic feet per ton of coal. The calorific value of coke is about 13,000 units, and that of the tar, if used as a fuel, is considerably more. So that Mr. Segundo's 1,722 units can fairly be reduced to something under 1,400, and the theoretical efficiency of a good gas engine is certainly not less than 11 or 12 per cent. Taking the heat used as 1,400 units, and that of the gas at 620, we have something to make gas engineers thoughtful. In these utilitarian days that 780 units ought not to be allowed to go to waste. Considering the maximum efficiency that can possibly be obtained by each class of engine, the author arrives at a limit of 60 per cent. for the gas engine and 18 per cent. for the steam engine. These figures, as compared with those above given, represent the margin for further economy. It is interesting to observe that the gas engine has not advanced so far as steam; but of a possible 60 it has as yet only scored 11 or 12, while the steam engine has approached to half of its maximum. The author passes on to consider the electric generator plant using steam and shows that the chief cause of the discrepancy between theory and practice is the varying load factor. Comparing practical working results of electric companies with those of the London Hydraulic Power Company, he finds that the latter can distribute power equivalent to one kilowatt hour for 1½d., but the former cannot get this result under 3½ to 4½d. But the loss of power in conversion into electricity puts the two on about the same level so far as lighting is concerned. Out of 14,500 units liberated by 1 pound of coal, 1,044 re-appear as useful work in the hydraulic, and only 478 in the electric distribution; but for the production of electric light the figures are 620 and 600 respectively. The direction in which to look for a reduction in this waste is the decreasing of the number of transformations of energy, or the increasing of the efficiency of such transformations. The distribution of hydraulic power appears to be attended with a loss of only 1 per cent., while that of distributing electricity is said to be rarely less than 12 per cent. The use of gas engine stations at various points for the generation of electricity is considered at length, and quoting from a practical experiment at Bradford, with gas at 3s. 3d. per 1,000 cubic feet, the cost per kilowatt hour is put at 3d., which is cheaper than the electric companies can do it. The author's remarks on this subject are characterized by fairness and good sense. When it is remembered that gas for engines can be obtained in most of our large towns at 2s. 0d. to 2s. 3d. per 1,000 cubic feet, it is evident that the use of gas furnishes by far the most economical way of generating electricity for electric lighting.

Street Lighting with Incandescent Gas Burners.

The *Gas World* thus discusses a copy of a report recently made by Herr Muchall, manager of the Wiesbaden gas works, detailing the results of experiments he has been making with Welsbach burners as applied to street lighting: As this subject is now engaging the earnest attention of many gas managers, a *precis* of Herr Muchall's report cannot fail to be of interest. At first Herr Muchall was very doubtful about the applicability of the Welsbach lamp to outdoor lighting, but a preliminary trial with one lamp resulted so favorably that he proceeded to erect 37 lamps in the public streets. This was done in December, 1892. The lanterns required no alteration to adapt them to the Welsbach burner. These lanterns are 4-sided, with closed top, and are provided with reflectors of enamelled iron or porcelain. Contrary to the

usual custom, the reflector is fixed point downwards—an arrangement which spreads the light outwards, instead of down into the lantern where there is already sufficient light. The lantern is also provided with an outside lighting arrangement, invented by Herr Muchall, which permits of the bottom flaps being closed in with glass; thus securing a practically windproof lantern. The lighting arrangement is placed between the reflector and the top of the lantern, so that it cannot be seen; and it is an admirable guard against wind and rain—so much so that in the severest storm only a flickering is noticeable; extinction of the flame, or even strong flickering, has never been observed.

From observations made during the winter of 1892–3, Herr Muchall draws the following conclusions: A good pressure is desirable; notwithstanding the tiny orifices, the burners are no more liable than ordinary burners to choking by naphthaline or to freezing; atmospheric deposits of any kind had no noticeable effect; neither great cold nor strong wind had any bad effects; but there is reason to believe that a moist atmosphere has a tendency to break the mantles from the top. Except one of mica, all the chimneys were of glass; they became dirty very slowly, and most of them broke before cleaning was necessary. As regards the lanterns and reflectors, these required cleaning much less frequently than do the lanterns fitted with ordinary burners; also, they are much more durable, on account of their being protected from the heat by the chimneys.

Maintenance consists principally of renewals of mantles and chimneys. The breaking of a chimney usually results in the breaking of a mantle; and the breaking of a chimney is the result of a faulty mantle. When a hole is formed in the mantle the blow flame thus created causes the chimney to be unequally heated, and finally it breaks, breaking also the mantle. When a mica chimney is used the blow flame causes that portion of it upon which it plays to, more or less, lose its transparency. When this happens it is desirable to turn the dull side towards the houses, or the chimney may be turned upside down—to enable this latter to be done the chimney should be straight, not conical.

For supporting the mantles cast-iron rods are better than magnesian ones; they burn out more rapidly (within a couple of months), but they do not break so readily. The fork of the rod should not be too flat, but ought to be deep.

At the end of March, 1893, an additional 33 lanterns were fitted, and observations were continued throughout the summer months. At this time it was observed that some of the burners were choked, and on investigation it was found that this was due to accumulations of insects; the insects, attracted by the brilliant light, had crept through the crevice of the lantern and through the four openings of the bunsen tube into the interior of the burner. This was remedied by covering the holes of the bunsen tube with fine wire gauze. The gauze also prevented firing back, which had been occasionally observed.

It was also observed that the cross tube leading outside became in time covered with salts resulting from the products of combustion (especially carbonic oxide), with vapor, acting upon the brass. This, however, is easily remedied by instructing the lamplighter to pass a cleaner through the tube when lifting off the burner.

The duration of the chimneys and mantles for each lamp was carefully noted, and in his report Herr Muchall tabulates the results thus obtained. The ultimate result reached is that for 1,000 hours' use there is required 1.90 chimney and 1.42 mantle. The average duration of the chimneys was found to be 531 hours and of the mantles 705 hours; the longest duration for a chimney was 1,920 hours and for a mantle 1,493 hours. A mantle which lasted 2,000 hours was tested photometrically at various stages of its life. The consumption was 100 liters (1 liter equal 61.016 cu. ins.) per hour, at 40 mm. pressure; and the photometric results obtained horizontally were as follow:

After	100	hours	60	candles.	After	900 hours	54 candles.
"	200	"	60	"	"	1,000 "	52 "
"	300	"	56	"	"	1,100 "	53 "
"	400	"	56	"	"	1,200 "	52 "
"	500	"	58	"	"	1,600 "	48 "
"	600	"	58	"	"	1,700 "	47 "
"	700	"	56	"	"	1,800 "	47 "
"	800	"	56	"	"	2,000 "	46 "

It was now tolerably certain that the new light would not be more expensive, and in all probability cheaper, than the old; leaving the threefold illumination out of account. This was after an experiment extending from the middle of December, 1892, to the middle of July, 1893. More lamps were now erected; and at the end of September there was a total of 242 in use. Observations were continued as before, with the result that at the end of September, taking the experiment as a whole, it was found that 1.17 chimney and 1.73 mantle were required for 1,000 hours. The medium duration of the chimney was 589 hours and of the mantle 579 hours; the longest duration of a chimney was 1,921 hours and of a mantle 1,741 hours. More lamps were now erected, and on the 1st of January last the number in use was 305.

Observations were continued, and these lead Herr Muchall to the following conclusions: The duration of the mantle does not depend, in the first instance, upon the number of hours but upon exterior circumstances—accidental breakage, street vibration, cleaning of the lantern, lighting, storms, rain, damp atmosphere, etc., and that the chimney and mantle last longer upon brackets than upon street candelabra.

Coming to cost, Herr Muchall estimates that for 1,000 hours chimneys will cost 0.90 mark and mantles 3.42 marks (1 mark equals 25 cents), both inclusive of cost of fixing. The initial cost of the burner is 12 marks; 20 per cent. depreciation, 1.04 mark; lighting, extinguishing, cleaning, etc., 7 marks (the same as for ordinary lanterns), gas, 100 cubic meters (1 meter equals 35.317 cubic feet), at 10 pf. per meter, 10 marks; total for 1,000 hours, 22.36 marks, as against 25 marks for ordinary street illumination by flat-flame burners. But in the latter case Herr Muchall allows nothing for depreciation; only 18 marks for gas and 7 marks for lighting, etc. He, however, points out that by the incandescent system from 2½ to 3 times more light is obtained.

ITEMS OF INTEREST FROM VARIOUS LOCALITIES.

THE proprietors of the Ironton (O.) Gas Company are very well satisfied with the result of the reduction in rates which went into effect on May 1st. The new schedule is appended:

Monthly Consumption.	Gross, per 1,000.
2,000 cubic feet and under	$1 25
2,000 " to 4,000 cubic feet	1 20
4,000 " to 6,000 "	1 15
6,000 " and over	1 10

A discount of 10 cents per 1,000 is allowed on all bills paid before the 10th day of the month in which they are presented.

MR. HENRY PADAN, President of the Portsmouth (O.) Gas and Electric Company, is also out with an announcement of a reduction in the gas rates, the same to have effect on all gas sent out on and after July 1st. The schedule is appended:

Monthly Consumption.	Rate, per 1,000.
1,000 to 5,000 cubic feet	$1 50
5,000 to 10,000 "	1 35
10,000 to 20,000 "	1 25
20,000 and upwards	1 15

AT the special meeting of the shareholders in the Consumers Gas Company, of Montreal, Canada, held for the purpose of considering the advisability of increasing the capital stock to $750,000, from $500,000, it was decided to sanction the new issue.

THE executive management of the proposed new Citizens Gas Company, for Kalamazoo, Mich., is composed of the following: President, O. M. Allen; Vice-President, J. W. Osborn; Secretary, Frank Henderson.

THE San Diego (Cal.) Gas and Electric Light Company is adding considerably to its main system this season.

WE understand that the Norwalk (Conn.) Gas and Electric Light Company has been put in the hands of a receiver, by order of Judge Thayer, of the Superior Court. The application was made at the instance of the Company itself.

THE following is from the New York *Journal of Commerce* of recent date: "For three months or so a 'war' has been in progress among the Gas Companies of Brooklyn. Mains have been laid in competitive districts by nearly all the Companies, and the price has been reduced from $1.25 to $1 per 1,000 cubic feet. The Fulton-Municipal Company has evidently determined to force the matter, however. It announced, June 21st, that on and after July 1st the price of gas to all consumers would be 90 cents per 1,000 feet, and sent out a large number of canvassers to solicit new business at that figure. The news caused uneasiness among the other Companies, particularly among officials of the Nassau, the Metropolitan and Williamsburgh Gas Companies. The latter say that the Fulton-Municipal Company cannot manufacture gas and sell it at a profit at 90 cents per 1,000, because the Williamsburgh Company could

not do so. A representative of the Fulton-Municipal Gas Company said yesterday that his Company was making a very cheap gas by the water process, using very little coal and utilizing the bye-product of naphtha supplied by the Standard Oil Company. The fight is led by H. H. Rogers, the Vice-President of the Fulton-Municipal Gas Company, who has long been identified with the Standard Oil Company. President Jourdan, of the Fulton Company, has said that next autumn they would make the price 75 cents per 1,000, and even lower, if necessary, as they could make a profit at that figure. The pipes of his Company now gridiron all of the newer portions of Brooklyn, and a great deal more is being laid this summer. In fact, the Company is putting down pipes far out in the environs, where it would seem to be competing with the parlor light oil of the Standard Oil Company in the tank business that has been carried on by the Dreyer Brothers for the Standard Oil Company for many years. The contest, though not the rate cutting, actually dates back as far as 1892. When J. Edward Addicks had secured control of the old Brooklyn Company, the Directors of the Metropolitan Company decided that it would be greater economy for them to manufacture gas than to purchase it from the Fulton-Municipal, as had been done for 10 years. They notified the latter Company that, on Jan. 1, 1893, the Metropolitan would cease to be its customer. They issued bonds and proceeded at once to fitting up and extending their gas plant, which had remained idle, save in the instance of its storage department. The clever managers of the Fulton-Municipal grasped the possibilities of the situation at once. The Citizens Company had ceased to purchase its product from their Company in 1890, and the contract with the Union Company had not long to run. The Brooklyn Company was under the control of Mr. Addicks, who would be unlikely to renew the pooling agreement between the two Companies, which was to expire on May 1, 1893. Mr. Addicks was likely to secure possession of other Companies, which would be placed in a position antagonistic to the Fulton-Municipal. The pooling agreement with the Nassau would expire on April 1, 1894. Because of these things and the various possibilities they presented some action was necessary. This was taken. Very quietly, during that summer and autumn, the Fulton-Municipal plant was extended and perfected until it had a daily capacity of 5,000,000 cubic feet, and contracts were made for many miles of mains. The Company was placed in a position to assume the aggressive at a moment's notice. By October all this had been done, and, on October 6 General Jourdan announced, in an interview with a reporter, that his Company was prepared for a 'contest for business,' which would result in the 'survival of the fittest.' In January, 1893, Mr. Addicks secured control of the Metropolitan Company. This did not tend to make the Fulton-Municipal more peacefully inclined. On March 28th, 1893, the latter put canvassers in the former's district. On April 17th it began to lay mains, and on May 22d commenced to serve gas to the Metropolitan's customers. That fight was prosecuted without any reduction of price and little resulted one way or another. The next development was at the next annual meeting of the Williamsburgh Company, when the Standard Oil representatives were left off the Board of Directors. On August 27 the Fulton-Municipal received the lease of a holder from the Peoples Company and commenced to lay mains in the Williamsburgh's district. It did this because of three reasons, as follows: The Williamsburgh Company had failed to re-elect the Standard Oil Directors; it had refused to pay an annual royalty for the use of the Tessie du Motay process, which it did not need, and it had refused to buy naphtha from the Standard Oil Company above the market price. On September 13th the Williamsburgh began to serve gas in the Peoples district, which was supplied by illuminating product bought from the Fulton-Municipal. A few days later the Fulton-Municipal began to serve gas in the Williamsburgh's territory, and late in September the Peoples took a hand in the fight. The Williamsburgh, on October 2d, through the Greenpoint Company, which it controlled, cut the price to $1 in the Peoples district. It is not unfair to say, and, as a matter of fact, it is admitted that this action on the part of the Williamsburgh secured many customers for it in the Peoples district. In December the Peoples Company applied to the Attorney General for permission to bring suit for the forfeiture of the Williamsburgh's charter, on the ground that it was charging two prices. This was headed off by the latter Company, which offered the discount of 20 per cent. throughout its entire district as well as in the Peoples territory. This brought back most of the customers which had left, and thus ended the campaign of 1893. There was a strong feeling for peace early this year, and Alexander E. Orr, President of the Metropolitan Company, sent letters to all the other Companies, asking them to appoint representatives to a general conference. This was done slowly, and meanwhile the Beckton Construction Company absorbed the Citizens, which, up to that time, had been a firm ally of the Fulton-Municipal. On March 14th the conference met, talked and decided that 14 was too large a committee, and that 7 would be a better number. That was all it did; no committee of 7 was appointed. The Fulton-Municipal prepared for an aggressive campaign as soon as the Legislature should adjourn. It bought land in the 18th Ward, adjoining the Nassau district, where it is constructing a holder station, and also began to lay mains there and in the Citizens district, and now comes the cut in the price to $1."

JUDGMENT for $6,163 has been entered against the Standard Gas and Electric Company, of Suffolk county, L. I., in favor of the Kerr-Murray Manufacturing Company, of Fort Wayne, Ind., on a note and draft which were not taken up at maturity.

THE Santa Barbara Gas Company, of Santa Barbara, Cal., has been reorganized.

A PROPOSITION for a franchise for a gas works at Snohomish, Wash., has been presented to the local rulers, the promoters of the same estimating that $20,000 will be a sum sufficiently large to establish the initial plant.

AT a meeting of the stockholders of the Paterson (N. J.) Gas Light Company, held at the office of the Company, Paterson, N. J., on Wednesday, June 20, 1894, the following were chosen Directors for the ensuing year: John Reynolds, W. L. Williams, James Dunn, John H. Reynolds, John S. Cook and A. S. Allen. At a subsequent meeting of the Directors, Mr. John Reynolds was elected President and Treasurer; Mr. W. L. Williams, Vice-President, and Robert Schoonmaker, Secretary.

"OBSERVER" forwards the following, under date of June 21: "The Massachusetts State Board of Gas and Electric Commissioners, after an exhaustive and complete hearing of both sides, has decided not to allow the Berkshire Heat, Light and Power Company to enter this town with its current and compete with the Great Barrington Electric Light Company, which decision was rendered some days ago in Boston. The decision of the Commissioners, which was written by Gen. Morris Schaff, revokes the permit of the Selectmen on the ground that no substantial advantage could, in the end, result from the admission of the new Company; that it was shown that the necessary capital which the new Company would require would not be materially less than that which is now invested by the old Company, and at the present rate the new Company would not be able to pay a reasonable dividend; and, furthermore, sooner or later, it would be obliged to raise prices to a figure which would allow a reasonable return from the investment. If the people of Great Barrington desire an all night electric service which would no doubt be desirable, they can have it provided they are willing to pay for it, and any just complaint of lack of efficiency of service can be brought before the Gas Commissioners, and, if deemed reasonable, will secure such action as they may think advisable. No evidence was put in at the hearing to show that the old Company had forfeited any of the rights secured to it under the statute."

MR. SILAS W. MOORE, Manager of the Lima (O.) Electric Light and Power Company, died on the 22d inst. He was for many years Vice-President of the Lima National Bank, and was also a veteran of the late war.

MR. J. C. ROSS, who was recently appointed Superintendent of the Perth Amboy (N. J.) Gas Company, evidently is of the progressive order, for he has not only given notice of a reduction in the selling rate, but also states that the Company will hereafter lay service pipes, from the street main to the curb line, without expense to those wishing to become customers of the Company. The new selling rate is $2 per 1,000 cubic feet to ordinary consumers, and a discount of 5 per cent. is to be granted to those who use 5,000 cubic feet or over per month.

MR. GRADY has introduced a bill in the lower branch of Congress to provide that all illuminating gas furnished to consumers in the District of Columbia shall not be less than 22 candle power, by the Bunsen photometer, using the English Parliamentary standard argand burner, having 15 holes and a 7 inch chimney, consuming 5 cubic feet per hour; and the gas shall be free from carbonic acid, carbonic oxide, sulphureted hydrogen, ammonia or other impurities, which either diminish its illuminating power or cause it to be dangerous to the health of consumers; and it shall contain "such proportion of hydrogen as will completely consume the carbon and leave no amorphous carbon to smoke and blacken walls, fittings and furniture."

MESSRS. HECTOR DULANEY AND GEORGE ALEXANDER, composing the law firm of Dulaney & Alexander, have entered an injunction suit against the Louisville Gas Company, the action being intended to test the Company's right to charge a meter rent. The plaintiffs state that in the practice of their profession it frequently becomes necessary for them to use their office after night or late in the afternoon, when artificial light is indispensable. For many months, they say, they have been using gas furnished by the defendant. The latter, it is claimed, has a monopoly in furnishing gas to the city, and should plaintiff's flow of gas be shut off their office would become useless after dark. Plaintiffs say that, relying on the defendant's charter, which, it is claimed, provides that it shall furnish gas to consumers as long as they pay for it, they, at great expense, furnished their office with fixtures. Plaintiffs allege that on June 11, 1894, there was sent to them by the defendant a bill (27 cents) for the consumption of 200 cubic feet of gas. There was also included in the bill, it is claimed, a charge of 10 cents for meter rent. They sent the bill to the City Gas Inspector (Mr. John W. Breeden), with the request that he correct the bill, also inclosing 27 cents. The tender was refused by the defendant, it is alleged, and the additional 10 cents demanded. Plaintiffs claim that on the 21st they received from Mr. Breeden a certificate of the illegality of the "meter rent." The 27 cents was again tendered to and refused by the defendant. The latter then, it is claimed, threatened to stop the gas unless the sum demanded was paid. Plaintiffs ask an injunction to prevent this, and ask that the acceptance of the 27 cents be ordered.

WE are in receipt of a copy of the latest catalogue issued by the Messrs. Peck Bros. & Co., of New Haven, Conn., descriptive of their supplies for gas and water companies. Write to them for a copy; it is a handy thing to have on your desk.

AT the annual meeting of the Exeter (N. H.) Gas Light Company the following directors were chosen: William Burlinghame, of Exeter; Nathaniel Pierce and Edward Hatch, of Boston; and A. P. Brown and Odiorne Swain, of Malden. The Directors subsequently named the following executive management: President, William Burlinghame; Treasurer, A. P. Brown; Clerk, A. F. Cooper.

AT a special meeting of the South Boston (Mass.) Citizens Trade Association the committee, appointed to consider the best means of securing a reduction of the local gas rate, reported that it would be advisable to wait in the matter of applying to the Board of Gas and Electric Light Commissioners for an order until the Governor has appointed a successor to Col. John T. Wheelwright, whose term of office will shortly expire. The report was accepted.

THE Warren (Mass.) Gas Light Company is making extensive repairs on its retort house system.

AT a meeting of the Directors of the Montreal Gas Company, Ald. Hurteau was elected a member of the Board, replacing Mr. John Crawford, who was elected a Director at the last annual meeting of the Company, with the understanding that he would retire as soon as a Director satisfactory to the local French-Canadian interest could be agreed upon.

THE arbitration committee to raise the gas rate at Minneapolis, Minn., has "absorbed" much testimony, "expert" and otherwise, since it commenced its sessions. Among other things submitted was a report, by Prof. G. B. Frankforter, of the Minneapolis University, giving a composite analysis of the Minneapolis Company's gas, such analysis being the average of 20 separate experiments. To say the least, the analyses must have been fearfully and wonderfully made, for it appears that other expert testimony showed the power of the gas, during or about the time Prof. Frankforter was making his experiments in the other direction, to be an average of 24 candles. Now we submit that a water gas containing 16.1 per cent. of nitrogen must have decidedly peculiar qualities to yield 24 candles of illuminating value, or else the Frankforter method of analyzing must have been decidedly defective. The analysis figures are:

Carbon dioxide	5.6 per cent.
Oxygen	1.7 "
Heavy hydrocarbons	9.0 "
Carbon monoxide	20.4 "
Hydrogen	29.2 "
Marsh gas	18.0 "
Nitrogen	16.1 "
Total	100.0 per cent.

Another remarkable thing in connection with this is the fact that the aforesaid candle power was also obtained in face of the fact that the gas was loaded actually to the muzzle with 5.6 per cent. carbon dioxide. On the returns as given, we fail to comprehend the nature of Minneapolis gas, or Prof. Frankforter's methods.

JUDGE TRUAX has decided that the Elmira (N. Y.) Gas and Illuminating Company is responsible for certain notes (amounting to $200,000) discounted at certain banks by Col. D. C. Robinson, and indorsed by him as an officer of the Company. The defense was that the Company had received no benefit from the proceeds of the notes, which proceeds had been diverted by Col. Robinson to his use and benefit.

Fiber Tubes.

The manufacture of tubes from wood pulp has been carried on for many years in New York, and with continued experience the breadth of its application increases very widely. This tubing is made from mechanical wood pulp, which is agitated with water and rolled on a tube very similarly to what is known as the wet machine in the ordinary process of preparing wood pulp for the general market of paper manufacturing. After the wood pulp is wound to a sufficient thickness around the tube, and the extra amount of water drains away, it is placed on end and the interior mould is withdrawn, leaving the wood pulp tube, which is held on suitable supports and dried until all the water is evaporated. The further process consists of dipping it into a very hot solution of asphaltum and other materials, which penetrate the whole substance and give it other properties. The ends are then squared up and the threads cut, or taper finish is made in the usual manner of wrought iron pipe.

This material, when finished, possesses some very important qualifications. Its high electrical resistance renders it suitable for an underground conduit for electric wires. As a non-conductor it is free from being impaired by electrolytic action from earth return currents, which have become such a serious factor in impairing the water and gas pipes in cities where the street tramcars are propelled by electric motors using earth return circuits. Its resistance to acids and alkalies fits it for use in chemical works. As a non-absorbent of water it is free from any difficulties due to expansion and contraction. It has limitations in various respects. The bursting strength of the tube is said to be from 150 lb. to 250 lb. per square inch, according to the size. It can stand without impairment a temperature of 150°. In case of alteration and changes the work is done with the ordinary fitting tools made for use on iron pipe. These tubes are from 1¼ in. to 12 in. in diameter. There is a great range of applications of this material in the processes of industrial chemistry; also for underground conductors, by reason of its resistance to corrosion, and to electrical transmission, and also its freedom from being impaired by electrical action.

The Manner in Which Buildings Should Be Protected Against High Potential Currents.

Mr. L. S. Wells says that the lightning arresters, which are attached to the ordinary switchboards, serve the purpose for which they were designed with fair results so far as protecting offices from lightning is concerned, but experience shows that their efficiency is not absolute, even in this connection, and they merit but little consideration when confronted with a constant current taken from a trolley or electric light wire.

After giving the spring-jack arresters a thorough trial we have found them to be inefficient by reason of their failure to respond at all times to a heavy charge. In numerous instances the points of contact have become melted at the time they were called into service, and considerable difficulty has been experienced in consequence of dust or dirt being insinuated between the points, causing the circuit to open.

During the past two or three years this form of protector has gradually been substituted by spider-wire arresters, which I believe are a vast improvement over any device that has yet come to the surface, and I understand they are being generally adopted in the larger buildings throughout the country. A most important feature, however, is to have the arrester properly located and perfect connections. It should be situated near the entrance of the building, keeping a safe distance from all material susceptible to combustion, and I have in some instances deemed it advisable to have the arrester encased in a box, lined with asbestos, to prevent the liability of the ground plate becoming sufficiently heated to cause inflammable material to become ignited, or overcome the possibility of a conflagration from sparks or other causes. The wire leading to the arrester should be fireproof, and the ground wire should be of sufficient size to carry an abnormal flow of current without becoming heated. If still further protection is for any reason deemed necessary, safety fuses can readily be inserted at the switchboard, but under ordinary circumstances I do not consider this essential.

The Market for Gas Securities.

The break in Consolidated is at last at hand, and it is quite in line with that which well-informed people have been looking for. The cut rate in Brooklyn, where gas is now selling all round at 90 cents per 1,000 cubic feet, and the underhanded practices that certain New York Companies are engaging in to secure consumers, which practices virtually amount to a cutting of rates, have had their natural effect. Indeed, it is conceded all round that gas must go to a dollar a thousand, and such reduction means a decrease of 20 per cent. in the gross income of each Company, minus the increase in income that will naturally follow the increase in output at the lower figure. The quotations for Consolidated to-day (Friday) are 126¼ bid, offered at 128, a loss of 7 points in the bid price for the week. It will go lower, too. Mutual is strong, at 151, and Equitable is weak. Standard preferred is strong, at 80 bid. Brooklyn shares show no change, which is certainly remarkable considering the condition of things. The least said about the matter the better, for no one knows what the end is to be. Chicago gas is steady to strong, and we look for it to go higher. Baltimore is a shade easier, at 63⅛ to 63¼, and Bay State is neglected.

Gas Stocks.

Quotations by Geo. W. Close, Broker and Dealer in Gas Stocks,

16 Wall St., New York City.

July 2.

☞ All communications will receive particular attention.
☞ The following quotations are based on the par value of $100 per share.

	Capital.	Par.	Bid	Asked
Consolidated	$35,430,000	100	126¼	128
Central	500,000	50	100	—
" Scrip	220,000	—	100	—
Equitable	4,000,000	100	185	188
" Bonds	1,000,000	—	106	108
Metropolitan, Bonds	658,000	—	108	112
Mutual	3,500,000	100	151	—
" Bonds	1,500,000	—	100	102
Municipal, Bonds	750,000		—	—
Northern		50	80	95
" Bonds	150,000	—	—	100
Richmond Co., S. I.	348,650	50	50	—
" Bonds	100,000	—	—	—
Standard Gas Co—				
Common Stock	5,000,000	100	25	30
Preferred	5,000,000	100	80	—
Yonkers		50	112	—
Gas Co's of Brooklyn.				
Brooklyn	2,000,000	25	103	107
Citizens	1,200,000	20	50	—
" S. F. Bonds	320,000	1000	—	101
Equity Gas Light Co	2,000,000	100	—	—
Bonds	1,000,000	—	—	—
Fulton Municipal	3,000,000	100	130	132
" Bonds	300,000		103	—
Peoples	1,000,000	10	—	70
" Bonds (7's)	368,000	—	100	—
" " (6's)	94,000	—	98	100
Metropolitan	870,000	100	132	136
" Bonds (5's)	70,000	—	100	—
Nassau	1,000,000	25	—	155
" Otfs	700,000	1000	99	100
Williamsburgh	1,000,000	50	138	145
" Bonds	1,000,000	—	107	110
Out of Town Gas Companies.				
Bay State Gas Co.—				
Stock	5,000,000	50	14½	15
Income Bonds	2,000,000	1000	60	—
Boston United Gas Co.—				
1st Series S.F. Trust	7,000,000	1000	78	—
2d " " "	3,000,000	1000	57	58
Buffalo Mutual, N. Y.	750,000	100	120	—
" Bonds	200,000	1000	95	100
Citizens, Newark	1,000,000	50	155	160
Chicago Gas Company.	25,000,000	100	78¾	79
Chicago Gas Light. & Coke Co.—				
G't'd Gold Bonds	7,650,000	1000	81⅛	81½
Consumers Gas Light Co., Jersey City	2,000,000	100	—	58½
Bonds	600,000	1000	90	94
Cincinnati G. & C. Co.	7,000,000	100	192	—
Consumers Toronto	1,600,000	50	184½	187
Central, S. F., Cal			90	100
Capital, Sacramento, Cal			—	55
Consolidated, Balt	11,000,000	100	63⅛	63½
" Bonds	6,400,000		107	107½
Citizens Gas Lt. Co., Rochester, N. Y.	500,000	—	85	101
Bonds	250,000		—	—
Detroit Gas Co.—				
Con. Bonds			60	—
East River Gas Co., Long Island City	1,000,000	100	—	—
Bonds	500,000	100	89¼	—
Equitable Gas & Fuel Co., Chicago, Bonds	2,000,000	1000	—	101
Hartford, Conn	750,000	25	120	128
Jersey City	750,000	20	190	200
Louisville, Ky	2,570,000	50	125	130
Laclede Gas Light Co. St. Louis, Mo.—				
Common Stock	7,500,000	100	16¾	17¼
Preferred "	2,500,000	100	67	69
Bonds	9,034,400	1000	86½	86¾
Little Falls N. Y.	50,000	100	—	100
" Bonds	25,000	—	100	103

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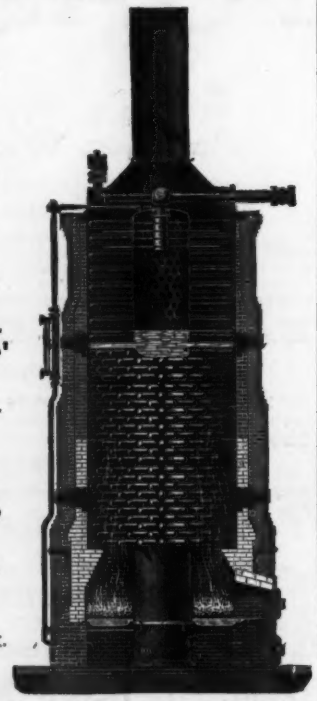

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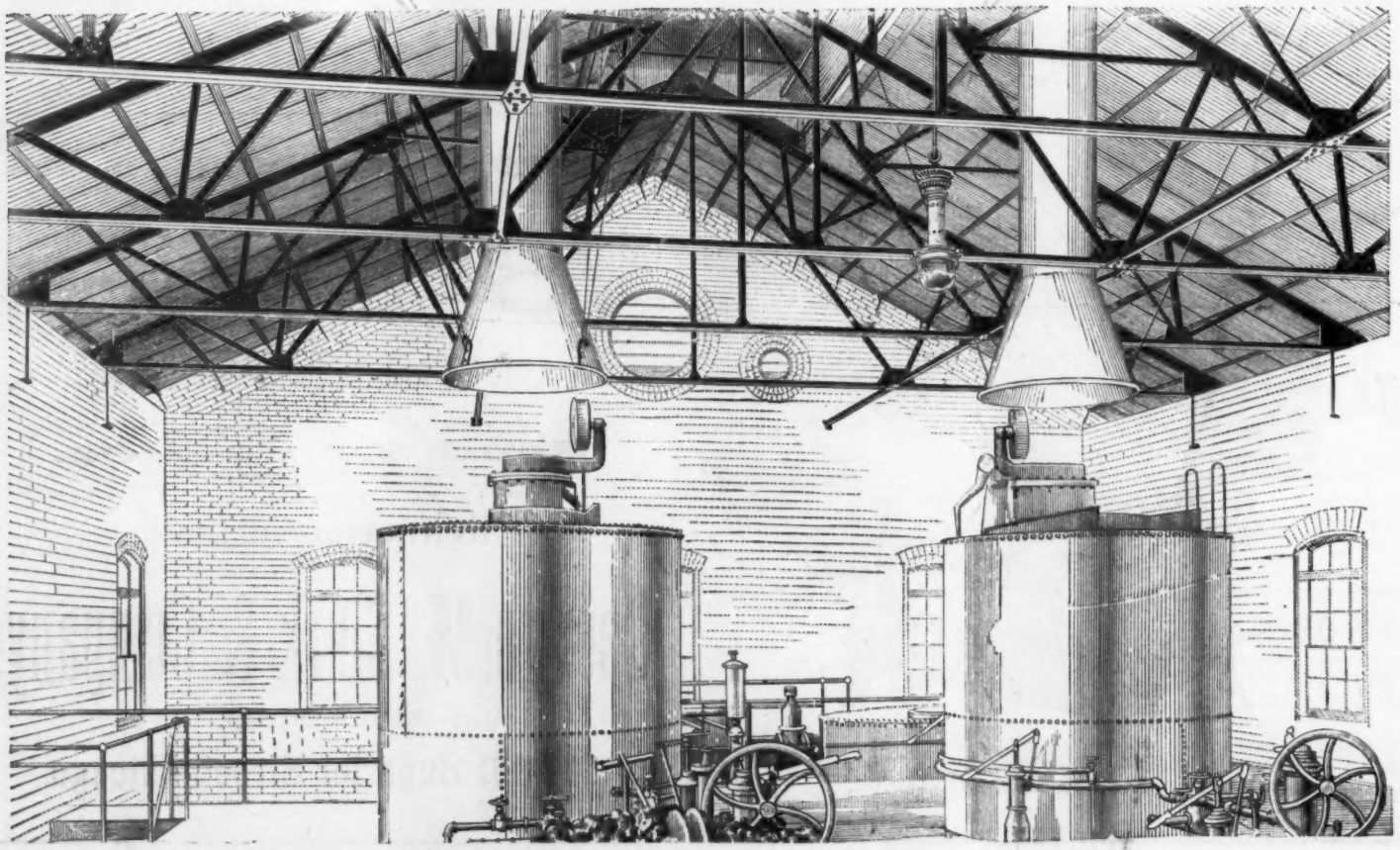

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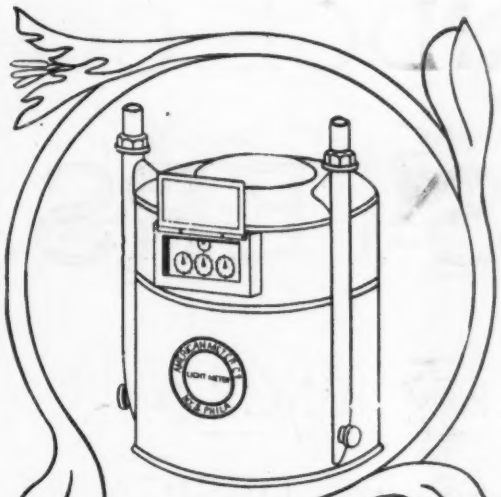

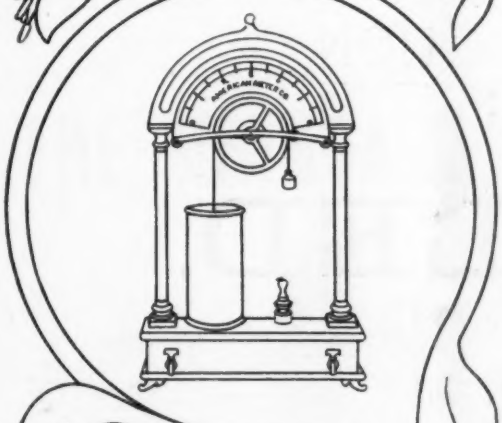

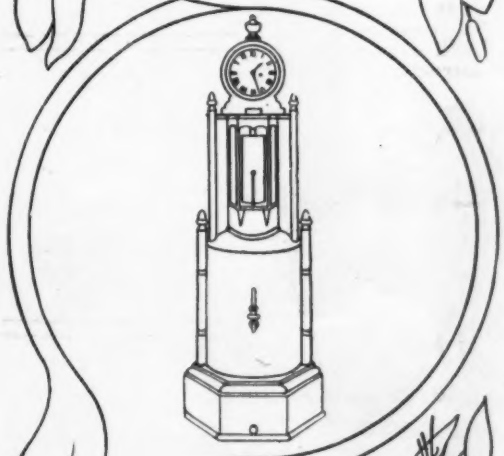

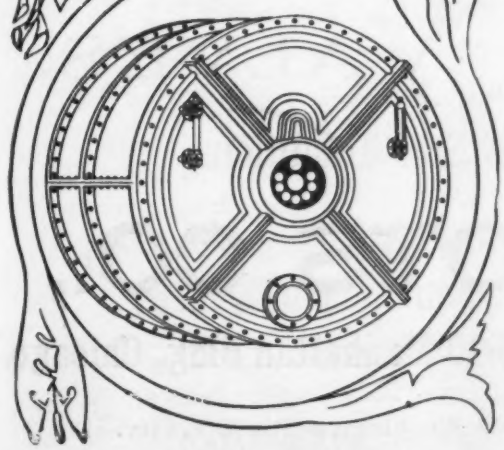

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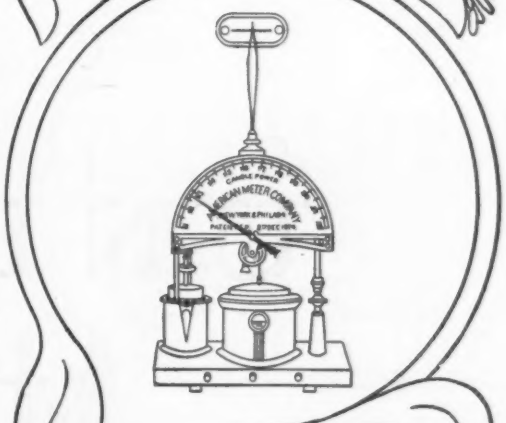
PUBLIC LIGHTING TABLE.

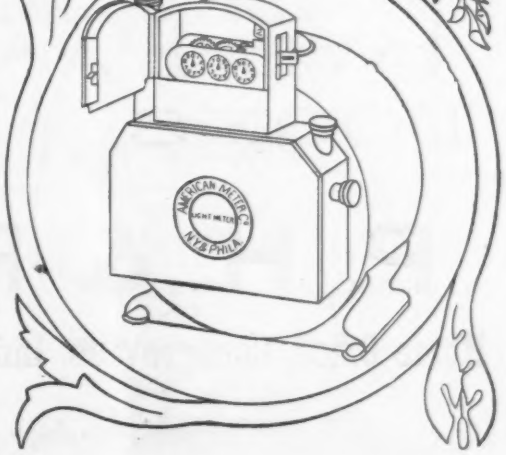
JULY, 1894.

Day of Week.	Table No. 1. Following the Moon. Date.	Light.	Extinguish.	Table No. 2. New York City. All Night Lighting. Light.	Extinguish.
				P.M.	A.M.
Sun.	1	8.00 PM	3.40 AM	7.30	3.15
Mon.	2	8.00	3.40	7.30	3.15
Tue.	3	8.00 NM	3.40	7.30	3.15
Wed.	4	8.00	3.40	7.30	3.15
Thu.	5	8.00	3.40	7.30	3.15
Fri.	6	8.00	3.40	7.30	3.15
Sat.	7	8.00	3.40	7.30	3.15
Sun.	8	10.10	3.40	7.30	3.15
Mon.	9	10.30 FQ	3.40	7.30	3.15
Tue.	10	10.50	3.40	7.30	3.15
Wed.	11	11.20	3.40	7.30	3.15
Thu.	12	11.50	3.40	7.30	3.15
Fri.	13	12.30 AM	3.40	7.30	3.15
Sat.	14	1.10	3.40	7.30	3.15
Sun.	15	2.00	3.40	7.30	3.15
Mon.	16	No L.	No L.	7.20	3.15
Tue.	17	No L. FM	No L.	7.20	3.15
Wed.	18	No L.	No L.	7.20	3.15
Thu.	19	8.00 PM	9.50 PM	7.20	3.15
Fri.	20	7.50	10.10	7.20	3.15
Sat.	21	7.50	10.30	7.20	3.15
Sun.	22	7.50	10.50	7.20	3.15
Mon.	23	7.50	11.10	7.20	3.15
Tue.	24	7.50	11.40	7.20	3.15
Wed.	25	7.50 LQ	12.00	7.20	3.15
Thu.	26	7.50	12.30 AM	7.20	3.15
Fri.	27	7.50	1.10	7.20	3.15
Sat.	28	7.50	2.00	7.20	3.15
Sun.	29	7.50	4.00	7.20	3.15
Mon.	30	7.50	4.00	7.10	3.30
Tue.	31	7.50	4.00	7.10	3.30

TOTAL HOURS LIGHTING DURING 1894.

By Table No. 1.	Hrs. Min.	By Table No. 2.	Hrs. Min.
January	244.10	January	423.20
February	195.30	February	355.25
March	206.20	March	355.35
April	169.40	April	298.50
May	162.10	May	264.50
June	135.40	June	234.25
July	146.30	July	243.45
August	162.20	August	280.25
September	174.10	September	321.15
October	211.20	October	374.30
November	221.00	November	401.40
December	245.30	December	433.45
Total	2274.20	Total	3987.45





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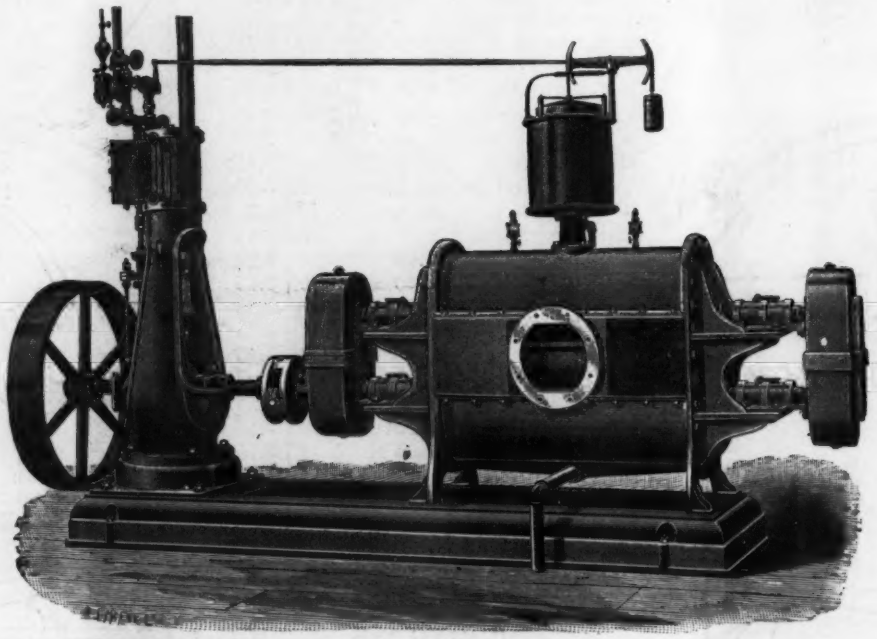

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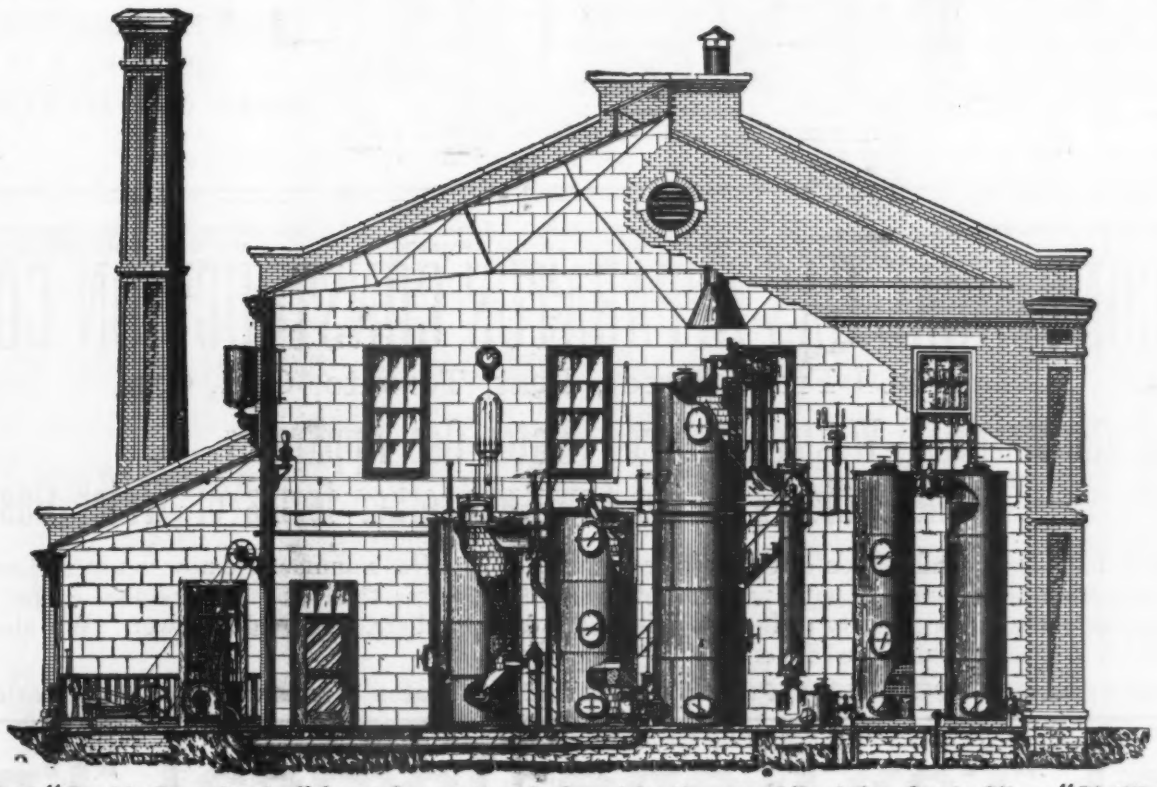

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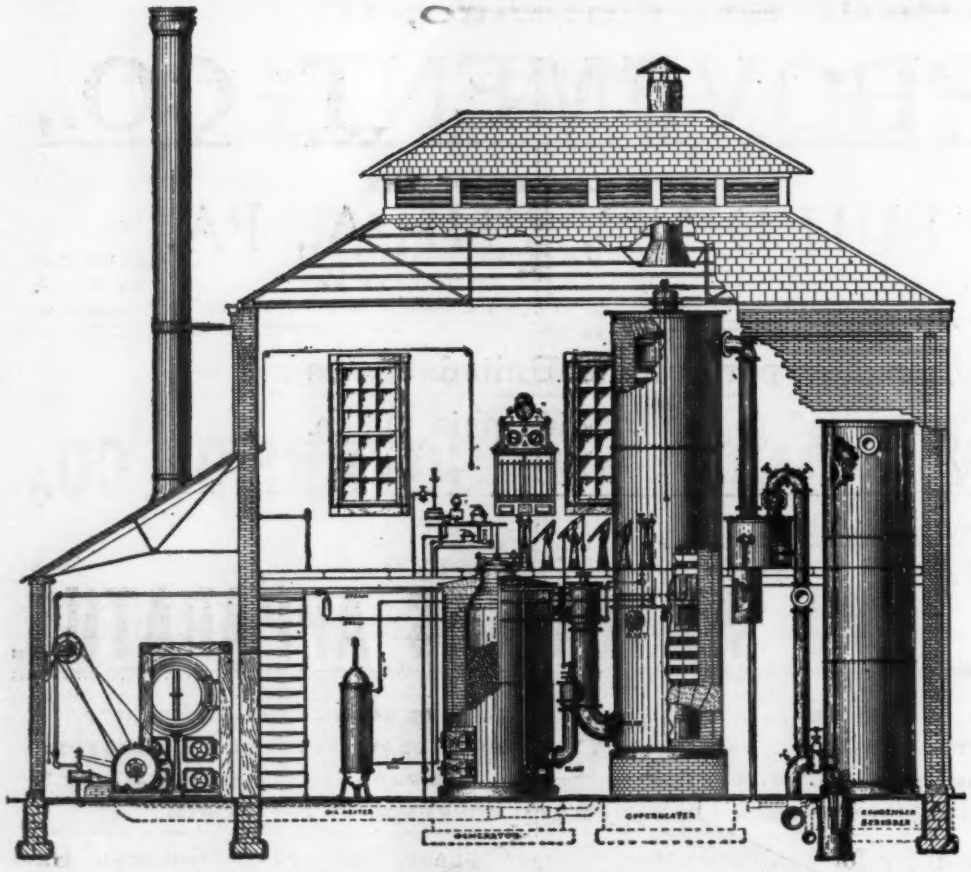

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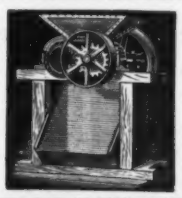

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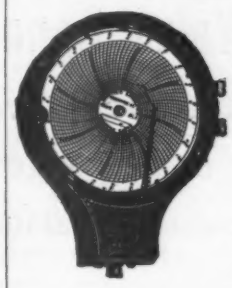

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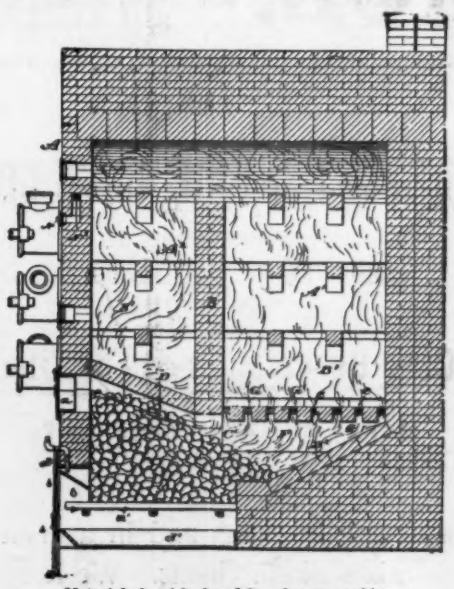

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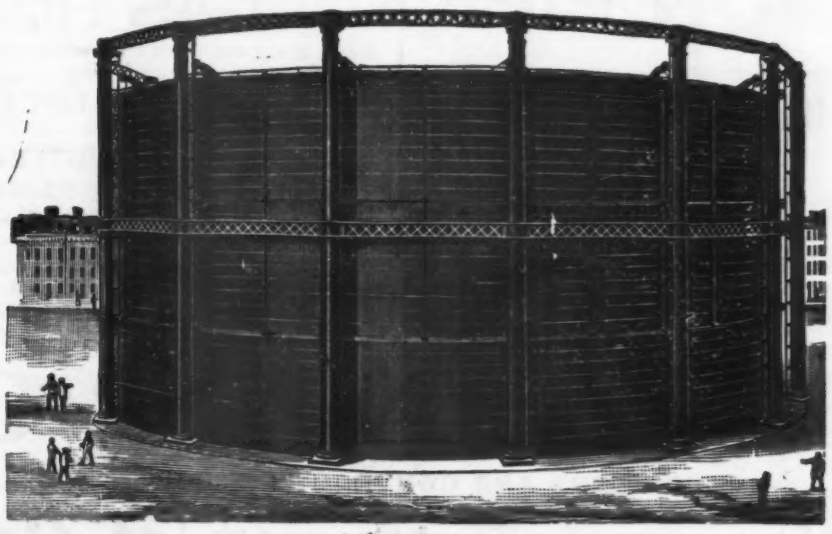

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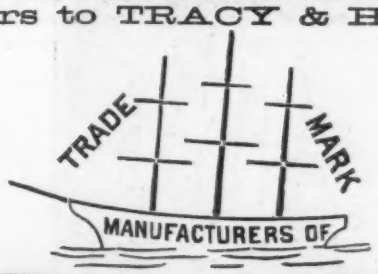

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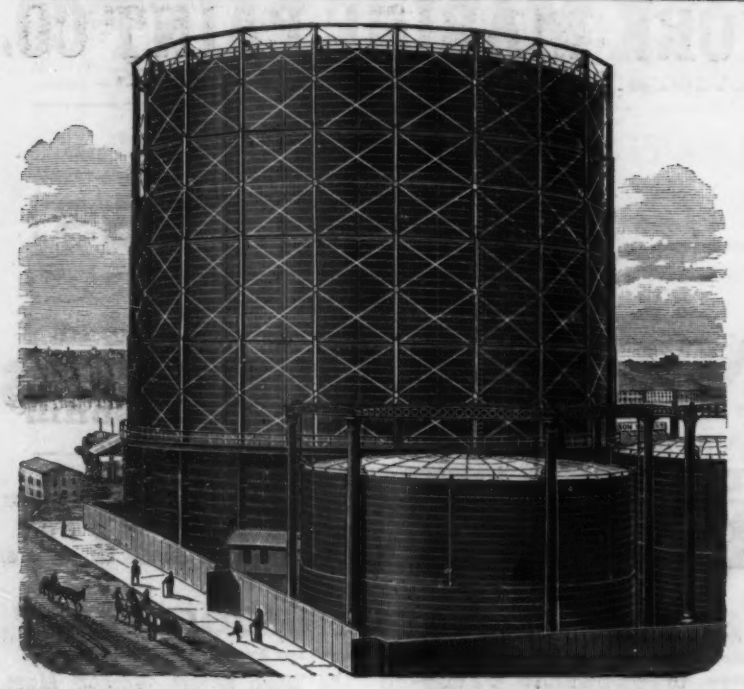

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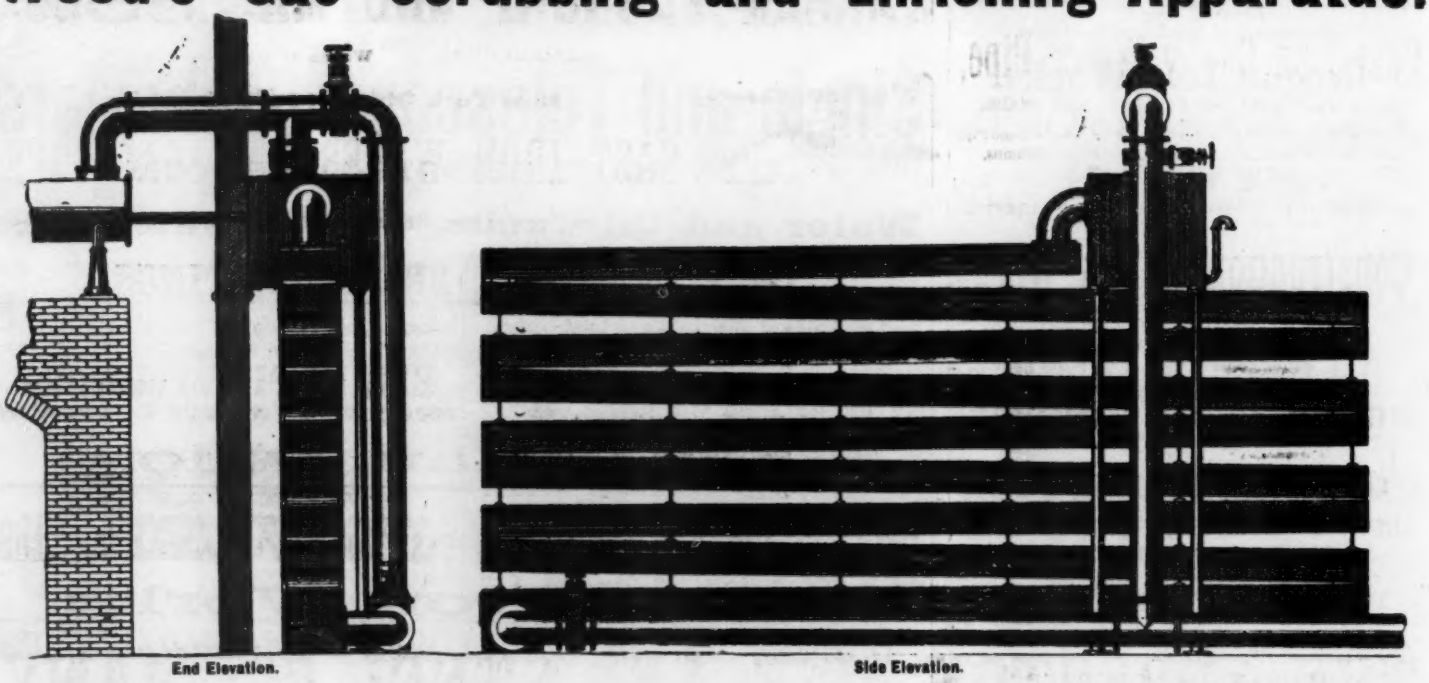

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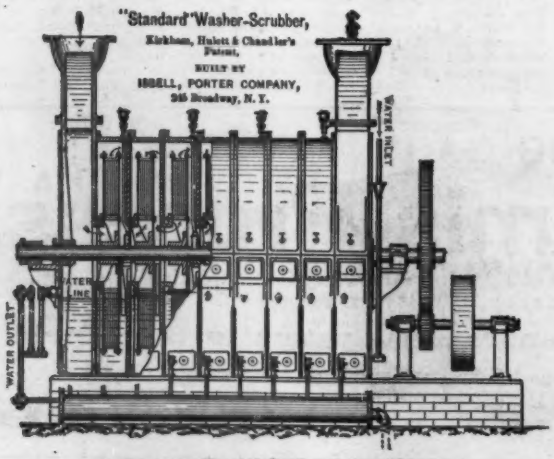

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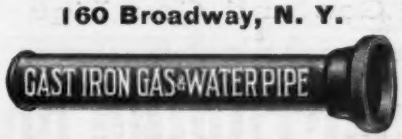

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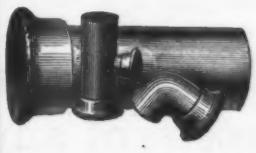

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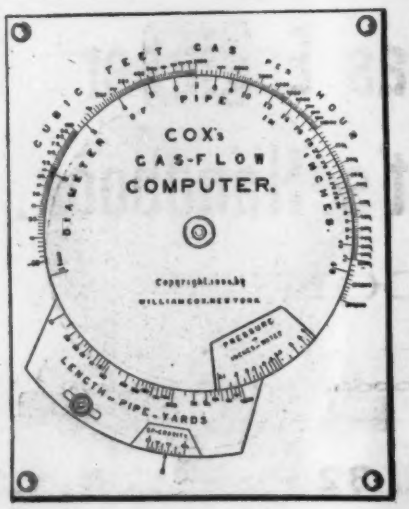

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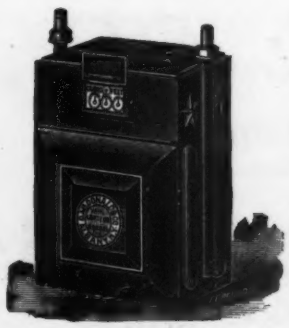

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